[PROC. ROY. SOC. VICTORIA, 32 (N.S.), PT. II., 1920].

ART. VIII.—*A contribution to the Palaeozoic Geology of Victoria, with special reference to the Districts of Mount Wellington and Nowa Nowa respectively.*

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(with Plates VIII., IX.).

[Read 14th August, 1919.]

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Wellington District, Map 1.

The area contained in Map 1 comprises about 90 square miles of mountainous country in a region previously unmapped geologically, except for a sketch map by Reginald Murray, issued in 1884, scale, 2 miles to an inch. Though the topography was roughly sketched in by him from main vantage points, very little of the area included in this map was examined geologically, hence as the margins of this region were mainly Upper Palaeozoic, he assumed that these rocks probably covered the whole area. A land survey was made some years ago of a limited portion centring round the serpentine rocks. The blocks were not permanently taken up, and only about one boundary fence was ever put up, so that very few points or lines other than parts of the Wellington and Dolodrook river courses could be definitely recognised in the field. These, however, were made use of, and formed the basis from which the existing map was constructed.

The important central portion, which includes the Cambrian and Ordovician inliers, has been accurately traced and mapped. The outlying topography has been determined approximately by a combination of rapid compass traverses, assisted by plane table methods from suitable vantage points.

Hickey's Creek Region, Map 3.

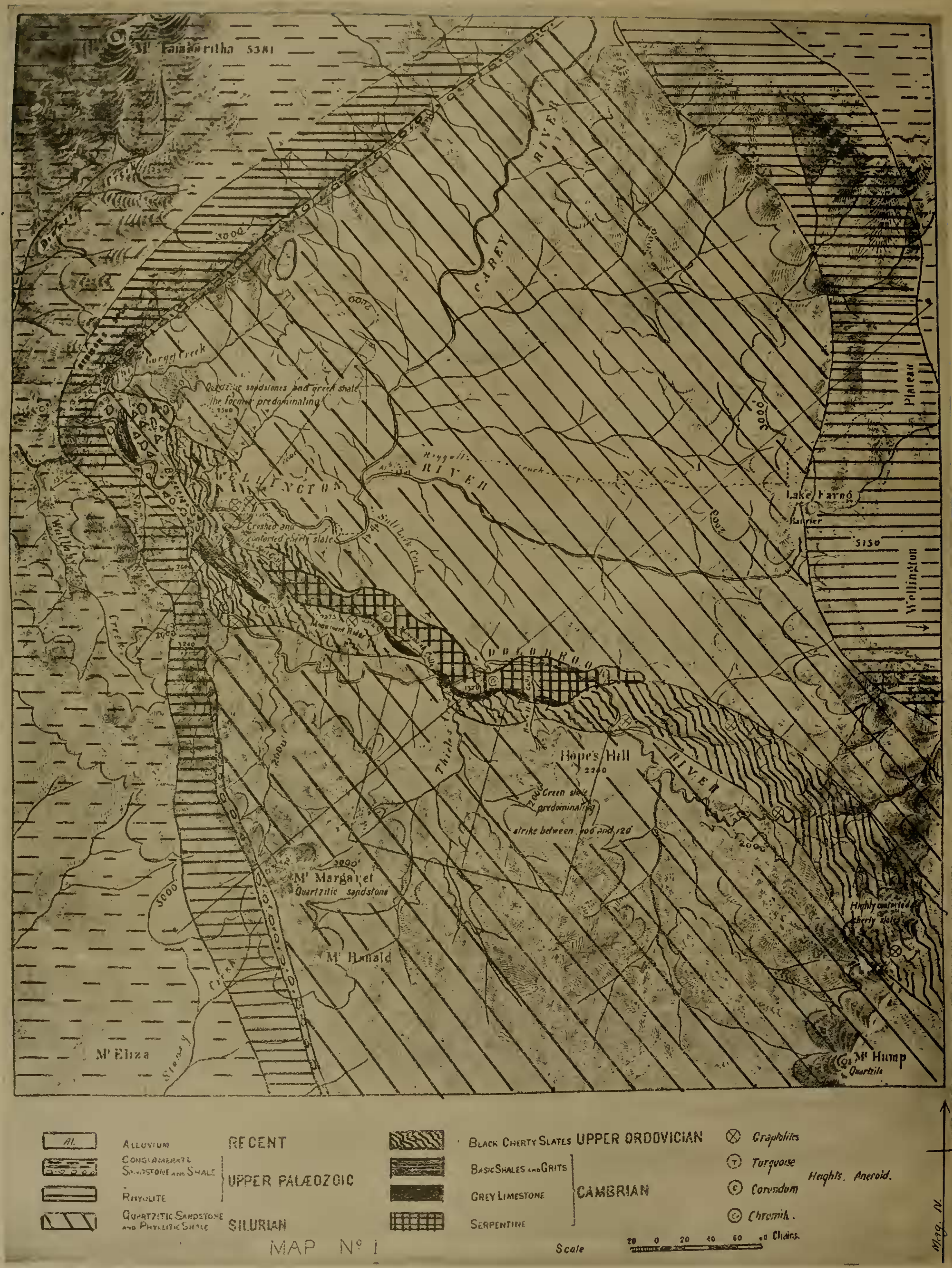
The only topographical basis for this map was the position and course of the Macallister River, obtained from the county map. The road was traversed by myself, and the rest of the features sketched in—in part by plane table methods and rapid compass traverses. Murray's Sketch Map also included this district, but no details concerning important structural features were shown.

Nowa-Nowa—Buchan District, Map 4.

This is another area little known geologically, with a very imperfect topographical basis to work upon. The main streams, such as Boggy Creek, Ti-Tree Creek, Yellow Water Holes Creek and Tara Creek, have been definitely located by Government surveys, and the roads and settler's blocks as indicated provide some fixed points from which to work, but practically the whole of the Tara Range, from its termination in the S.E., near Mt. Nowa-Nowa, to where it passes out of the map in the N.E., has only two fixed points shown in any of the existing maps, namely, the two trigonometrical stations of Mt. Nowa-Nowa and Mt. Tara.

The only other geological map which includes this area is the general map of Victoria, 8 miles to an inch. I understand there are some unpublished sketch maps in the hands of the Geological Survey of Victoria, upon which this portion of the general map was based, but I have not seen them.

The author spent about five weeks in this district, which covers an area of about 200 square miles. It was traversed on foot, single handed, so that though the boundaries indicated are all my own, they are necessarily only very approximate.



Map of Mt. Wellington Area.

Introduction.

The following observations and conclusions are the result of field work which was started in the vicinity of Mount Wellington, in North Gippsland, about fifteen years ago. It was the existence of a small, imperfectly known mountain lake, close to Mount Wellington, which first attracted the writer to this region. Lake Karng, as it has been named, had been visited by the late Dr. Howitt about fourteen years previously, but the question of its origin was not definitely settled. Of the two views discussed by Howitt (1 and 2), namely, glacial and landslip origin, the glacial was most favoured.

No other scientific observer had visited the lake until the writer's examination in December, 1904. A report of the excursion appeared in the "Victorian Naturalist," 1905 (11). The landslip origin of the barrier which forms the lake is there upheld, and several subsequent visits by the writer have greatly strengthened this conviction.

Incidentally, the first excursion showed that the whole region was full of interest, both geologically and physiographically, and during the years 1904 to 1908 (11, 12, 13), four short vacation expeditions were made into various parts of this district. The most important result of this preliminary work was to show that to the west of Mount Wellington there was an extensive and complex inlier of Lower Palaeozoic rocks in an area previously regarded as Upper Devonian. In this region, along the Wellington and Dolodrook Rivers, extensive outcrops of black cherty slates were discovered, yielding abundant and beautifully preserved Upper Ordovician graptolites. Serpentine containing Corundum and Chromite was also found to occur along a belt within the Ordovician area, but its age and relationship to the surrounding rocks had not yet been worked out. Several outcrops of grey crystalline limestone intimately associated with the slates and serpentine were next discovered, and these proved later to be some of the most important and interesting rocks of the district. At first a small brachiopod was the only fossil obtained, which Mr. Chapman regarded as a Silurian form, but later another outcrop of limestone yielded abundant trilobites, which Mr. Chapman confidently recognised as Upper Cambrian (13 and 15). This came as a surprise, for though the field observations were limited, they had not suggested the marked stratigraphical break which the palaeontological evidence now demanded. Shortly previously to this discovery, Mr. E. J. Dunn (16), late Director of the Geological Survey, in company with

Professor E. W. Skeats, made a flying visit to this region, spending only about four days there. Mr. Dunn's attentions were specially directed to the examination of the Serpentine, with the associated occurrence of the Corundum and Chromite, but the observations of both these geologists on the relations of the limestone to the surrounding rocks, though hurried, led them also to receive with some surprise the possibility of their being regarded as Cambrian.

A few years previously, in 1902, Professor Gregory, from a study of several Lower Palaeozoic areas in Victoria, but particularly in the vicinity of Heathcote, claimed that a Pre-Ordovician series of probable Cambrian age existed; and to which he gave the name Heathcotian. Professor Gregory's conclusion was not, however, accepted with full confidence by all the Victorian geologists, and later, Professor Skeats (18) examined carefully the Heathcote rocks, and in 1908 published a very comprehensive review of the situation, concluding that the evidence in favour of a Pre-Ordovician series at Heathcote was not conclusive. He therefore for the time being favoured the inclusion of the doubtful rocks in the basal Ordovician.

The Cambrian problem in the Wellington district was therefore of more than local interest since the existing knowledge concerning the occurrence of Cambrian generally in Victoria was in an unsatisfactory state. It was clearly the chief among many interesting and important questions awaiting solution in this region.

At this stage in May, 1908, the writer's departure to undertake geological exploration in Africa under the direction of the Imperial Institute, postponed indefinitely these interesting researches.

A paper was therefore written, embodying the conclusions arrived at, and stating also the more important unsolved problems (13).

Early in 1915, while in Melbourne, on a short holiday from Africa, the effect of the war led to the suspension of the African Exploration, and it was suggested by Professor Skeats and Dr. Summers that I should resume in the meantime the Wellington researches. The University offered encouragement and assistance in the form of a Government Research Scholarship, and the opportunity, therefore, to renew the work was gladly availed of.

The foremost aim of the expedition was to endeavour by careful survey to map and work out the relations of the various limestone outcrops to one another, and to the surrounding rocks. It was soon found, however, that the work grew in scope, for the mapping showed a succession of inliers ranging from Cambrian to Silurian, surrounded by a ring of Upper Palaeozoic sediments with associated acid and basic lava flows. Important broad structural and tectonic considerations involving palaeozoic geology generally therefore, became involved.

On the first expedition of renewed exploration in April, 1915, I was accompanied by my father, Mr. A. O. Thiele, who had been a constant helper throughout the numerous field trips to this area. Mr. Herman, Director of the Geological Survey, also kindly arranged for Mr. J. Caldwell, one of the officers of the Survey, to join the party as a field assistant, and I am greatly indebted to the willing and able help rendered by both these persons.

Various unavoidable difficulties, due partly to the season and partly to the rough nature of the country, prevented the completion of the work before the wet season set in, and as the district was unsuitable for winter field work, it was decided to choose another region in the meantime, offering unsolved problems likely to bear in some way with those of the Wellington region.

The district, therefore, between Nowa Nowa at the head of Lake Tyers and Buchan, was chosen, for it included two occurrences believed by Mr. Dunn to be of Heathcotian age, one in Boggy Creek and the other in the Tara Range (19), south-east from Buchan.

In Boggy Creek, just north of Nowa Nowa, Mr. Dunn had stated that diabases associated with cherts occurred and in the Mount Tara goldfields he had recognised cherts. Both these occurrences had been included in the Heathcotian on purely lithological grounds, but the relationship to the surrounding rocks had not been worked out. This district further offered an opportunity of studying a portion of the important belt of igneous rocks known as the "Snowy River Porphyries," thus affording scope to discuss the Palaeozoic volcanic history generally, of which the Wellington series form an important chapter.

These various journeys through Gippsland provided also some interesting physiographical studies, so that the extent of the work has gradually grown until it includes a number of distinct problems which will now be considered in turn.

WELLINGTON DISTRICT.

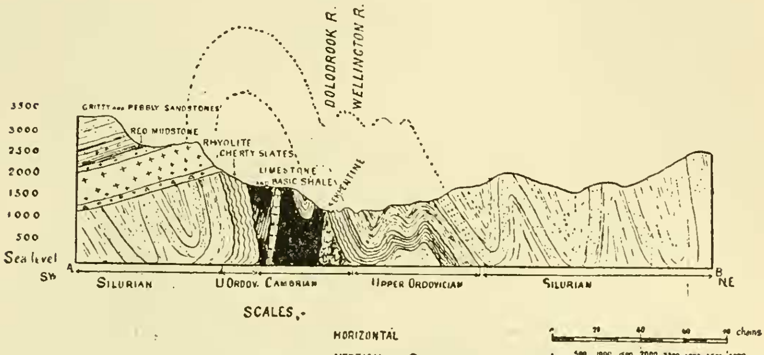
The Palaeozoic Geology.—The Wellington region forms part of one of the important major tectonic and structural zones of Victoria, which may be conveniently termed the Mansfield-Wellington zone. This belt bears the record of a long succession of tectonic volcanic and sedimentary events ranging practically throughout the Palaeozoic period, starting with Cambrian and closing with Lower Carboniferous. There are probably three distinct periods of igneous activity represented, namely, Cambrian, Lower Devonian and Lower Carboniferous. A succession of powerful fold and fault movements along a line varying between N.N.W. and N.W. acting at intervals throughout this period, has impressed especially in the older formation, some marked structural features in the form of intense folding, crumpling and crushing. A general parallelism in strike as a rule exists between the different formations, and the evidence of unconformities has to be considered very carefully. The problems of any portion of this extensive and mountainous belt should take note of the general features of the whole area as far as possible, but, unfortunately, much of the region is still very imperfectly known, and some of it has never been examined geologically. The Wellington area forms the southern end of the belt, and rises abruptly from the northern edge of the great Gippsland Plains, a little to the north of Heyfield, and forms a part of the great Central Highlands of Victoria.

The Mansfield region lies near the northern end, across the Main Divide, not far from the border of the Highlands with the northern plains. The length of the whole belt is about 100 miles, with a width up to about 40. Much of it is covered by Upper Palaeozoic sediments and igneous rock, but extensive denudation has in places stripped off this covering, and laid bare the older rocks, notably near Mansfield, in the Howqua Valley, and also in the Wellington and Dolodrook Rivers. The need for further work in the first and second localities will be explained later. The particular features of the Palaeozoic rocks of the Wellington area will now be taken in order and some reference made to related occurrences elsewhere in Victoria.

Pre-Ordovician Series (Heathcotian).—Under this division there are three distinct groups of rocks:—

(a) Serpentine	Pre-Upper Cambrian.
(b) Trilobite Limestone	Upper Cambrian
(c) Garvey Gully series of Sediments	

The general occurrence of this series is shown on the map of the Wellington region, and the accompanying Sections (Map No. 1 and Sections 1 and 2). It will be seen that the rocks of this series occur as a long, narrow curved inlier striking generally in a north-westerly direction, which is the grain or trend of the whole structure of the area. A narrow, incomplete ring of black cherty graptolite slates of Upper Ordovician age almost surrounds the inlier, but on the northern side along a portion of the contact the Silurian sediments rest directly against the Serpentine. The whole series is intensely crushed and contorted, and so are the Upper Ordovician

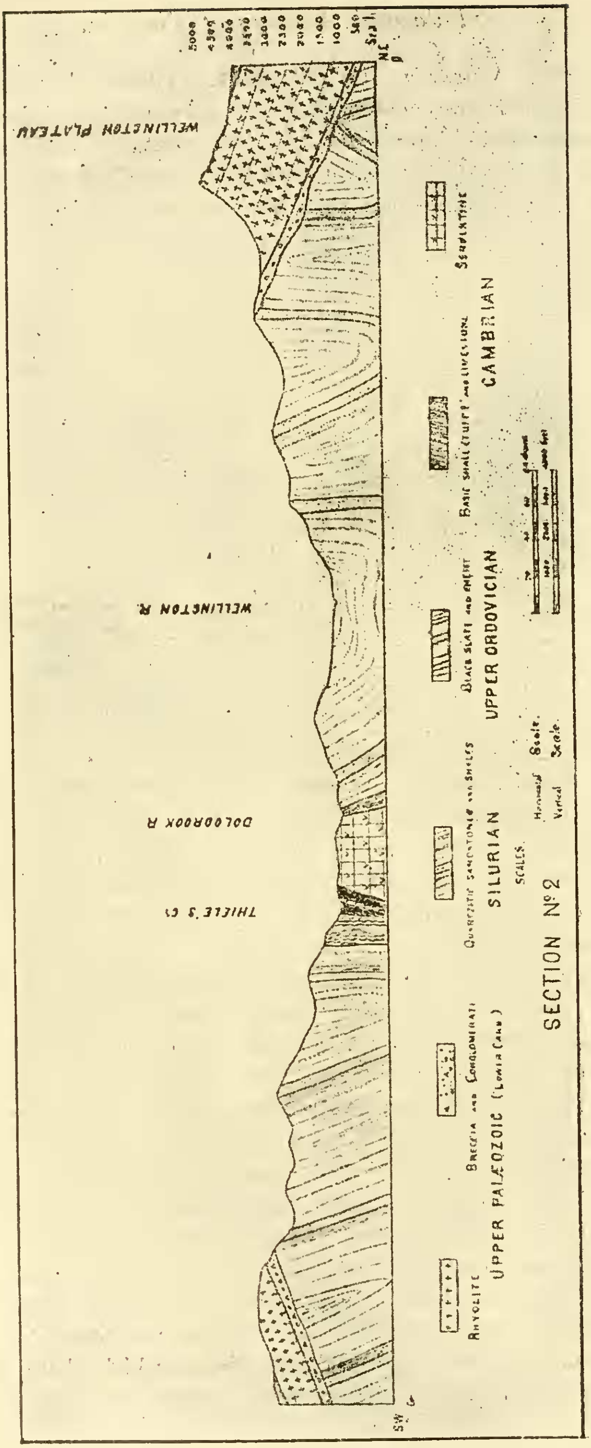


Section 1.

Section showing relation of Cambrian Inlier to surrounding Rocks
Dolodrook River

rocks. As all the successive formations have been subjected to periods of folding and compression along a north-westerly direction, they have a similar strike, and small vertical sections of contacts do not yield conclusive evidence of unconformity. The mapping, however, of the boundaries gives more satisfactory information in this direction, and everywhere the lithological and palaeontological break is quite sudden.

The Serpentine.—The extent and general features of this rock with its associated minerals, Chromite and Corundum, were described in a previous paper (13), but the age and relationship to the surrounding rocks had not been definitely established. The Serpentine was then regarded by me as the oldest rock occurring in this region, and was put down as Pre-Upper Ordovician. This view is still upheld, but it is now possible to further restrict its age to Pre-Upper Cambrian. The Serpentine was shown previously (13) to be of the nature of an altered intrusive rock, originating from both pyroxenites and peridotites. Various rocks are found directly in contact with it, for example, serpentinous grits, conglomerate and finer sediments derived from the denudation of the serpentine, also associated diabase tuffs in which there are definitely interbedded lenticular limestone deposits of Upper Cambrian


WELLINGTON PLATEAU
WELLINGTON R.
DOLODROOK R
THIELE'S Ck
SW
NE
RHYOLITE
BRECCIA AND CONGLOMERATE
QUARTZITIC SANDSTONE AND SHALES
BLACK SLATE AND CHERT
SERPENTINE
UPPER PALÆOZOIC
SILURIAN
UPPER ORDOVICIAN
CAMBRIAN
SCALES
Horizontal Scale
Vertical Scale
SECTION No. 2

age; elsewhere Upper Ordovician slate or Silurian sandstone and shale directly overlie the Serpentine. Nowhere has there been observed any rock showing contact alteration. The conclusion, therefore, is clear that not only is the Serpentine the oldest rock but there is a stratigraphical break between it and the next oldest rock, the Upper Cambrian, sufficient to allow of considerable denudation previous to the deposition of the Upper Cambrian. The intense shearing and foliated character of much of the Serpentine has been previously referred to (13). It is generally recognised that a certain amount of such structure frequently found in Serpentine is due to intense expansional forces generated by the increase in volume, which accompanies the mineralogical change from pyroxene and olivine into Serpentine. Additional stresses, however, of an intense character due to general compressional earth movements have further deformed these rocks, and have largely contributed to their schistose character.

A very useful and comprehensive summary of the state of our knowledge concerning the Heathcotian Series is given by Professor Skeats in the "Volcanic Rocks of Victoria" (18). It includes references to various Serpentines and associated rocks in Victoria, some of which have been doubtfully referred to by various geologists as Pre-Ordovician. Further interesting information and statements concerning Cambrian occurrences generally in Australia are discussed by Professors David and Skeats in the Federal Handbook, in the section dealing with the geology of the Commonwealth (20). Serpentine has been shown to occur in a number of widely-separated localities frequently associated with cherty and diabasic rocks, notably at Waratah Bay, near Casterton and the Limestone River, Benambra. These rocks have been doubtfully included by some authorities in the Pre-Ordovician Series, but though little is known concerning the relationship to the surrounding rocks, the definite fixing of the age of the Wellington Serpentine adds a little more weight to the conjecture that these other occurrences may be correlated with the Pre-Ordovician.

It is interesting to note as previously referred to by Professor Skeats (18) that near Heathcote the diabase at its margin passes into a rock allied to Serpentine, known as Selwynite, containing chromite and corundum, an association also found in the Wellington area.

The Garvey Gully Series.—These rocks were recognised in part in my previous paper (13), under the heading of "Sediments composed largely of Serpentine Detritus, and were doubtfully included in the Upper Ordovician. A more extended examination, however, has shown that they are distinct lithologically from the black slates; the junction is always a sharp one, and further the limestone deposits which have yielded definite Cambrian fossils are interbedded with them. Chemically, these rocks are distinct from the adjacent cherty graptolitic slates. Their analysis shows a low silica percentage and relatively high iron, lime and magnesia content. The soil, therefore, derived from their weathering is of a noticeable red colour and clayey character, supporting a richer growth of grass and other vegetation than the rather stony and sterile soil of the slates. The belt is further marked by a rather striking feature of the weathering of some of the fine grained sediments, which petrological examination proves to be tuffaceous. These rocks weather into striking elongate spheroids with a succession of spheroidal shells similar to the well-known structure of partly decomposed basalt and other igneous rocks. Their field occurrence and petrological examination, however, leave no doubt as to their sedimentary origin.

There are two separate occurrences of this series, both of limited extent. The largest and most important is a long narrow belt along the Dolodrook Valley. It starts about a quarter of a mile north-west of Garvey's hut, and extends south-easterly on the southern side of the Serpentine as far as Roan Horse Gully, a distance of three and a half miles. The greatest width is never more than a few chains. The other occurrence is a small outcrop of highly contorted basic sediments exposed in the bed of the Wellington River, roughly on the line of strike, about a mile and a quarter north-west from the termination of the first-named inlier.

At its north-western extremity, the Dolodrook inlier passes out of sight under the Upper Palaeozoic rocks, but along its southern or south-western boundary it is directly in contact with the Upper Ordovician slates. The character of the sediments varies from coarse serpentinous conglomerate through grits to fine greenish diabasic tuffs. Several sections merit special attention.

Locality A, (Dolodrook River).—This position is shown on the map extending from the junction of the Black-Soil Gully, in a south-westerly direction, for about twenty chains. The succession and relationship are represented in Section No. 1. At the junction of Black-Soil Gully with the Dolodrook, there is a small inlier of Serpentine with contorted black cherty slates in contact on the north side. The junction appears to be a fault, and obscure but recognisable Upper Ordovician graptolites can be traced in the cherts almost up to the junction. Following the river bed upstream, the Serpentine about one chain in width passed serpentinous and ferruginous shale of the Garvey Gully type, highly ferruginous here on account of weathering. The rock continues for about eight chains, when a hard cherty band of contorted slates is encountered. It is about two chains wide and definitely Upper Ordovician, from which characteristic graptolites have been obtained. At first sight, the band has the appearance of being interbedded with the Cambrian sediments, but palaeontological evidence supported by petrological differences and comparison with similar small outliers of Upper Ordovician in the vicinity, shows that the occurrence is due to intense folding which has nipped portions of the overlying Ordovician into the Cambrian. Continuing with the section, the cherts are followed again by a belt of about 10 chains of typical greenish basic tuffs with interbedded Cambrian limestone about one chain wide and beyond this to the south-west, these rocks are bounded by a belt of contorted Upper Ordovician cherts.

The contact between the two series is shown in a small gully which enters the Dolodrook at the limestone outcrop. It is situated about five and a half chains from the junction in a south-west direction. The passage from basic tuffs to cherty slates is sharp, with about two feet of gossany material in between, probably occupying a fault. The rocks are highly inclined and disturbed on either side.

A chemical analysis of the tuff is appended, showing its basic character.

	I.		II.
SiO_2	50.09		48.11
Al_2O_3	12.69		13.30
Fe_2O_3	5.30		3.70
FeO	12.01		8.10
TiO_2	2.12	MnO	1.43
CaO	5.08		8.48
MgO	5.60		9.51
H_2O-	0.40	Loss on Ignition	4.21
H_2O+	2.72		
Na_2O	2.54		1.96
K_2O	1.32		1.57
CO_2	0.80		—
	100.67		100.37
S.G.	2.86		

(I.) Green banded tuff—Garvey Gully series Dolodrook River (Teale.)

((II.) Purple and green tuff between Pen-Maen-Melyn and Pen-Maen-Foel, South Wales, Cambrian, (Wilson), British Petrography, Teall, page 223.

The principal differences to be noted in comparing the Dolodrook tuff with the Cambrian one of South Wales are the greater percentage of iron and smaller amount of lime and magnesia present in the former. No other analyses have yet been made of similar rocks of supposed Heathcotian age in Victoria.

Thin sections of the fine grained tuff (No. 44), from the Dolodrook, show a banded and somewhat schistose structure, with numerous small sub-prismatic and irregular grains of basic plagioclase felspar, many of which are orientated with their longer axes parallel with the planes of schistosity, but many also lie at any angle, frequently across the planes of foliation. Much chloritic and some serpentinous material is present between the felspar grains, but no fresh pyroxenes were distinguished. Magnetite is abundant, and several small grains of quartz were noted. The fragmental structure, together with the chemical and mineralogical composition seems to indicate the nature of an altered subaqueous diabase tuff.

The secondary silicification, which is one of the marked features of the diabase tuffs and allied rocks at Heathcote, is absent.

Locality B.—The next section of importance is about two and a half miles in a south-easterly direction, at the junction of Thiele's Creek with the Dolodrook. Here within a relatively small area there are good exposures of the Serpentine, the basic sediments with interbedded limestone, the Upper Ordovician graptolite bearing slates; and the Silurian sandstones and shales (Map 2).

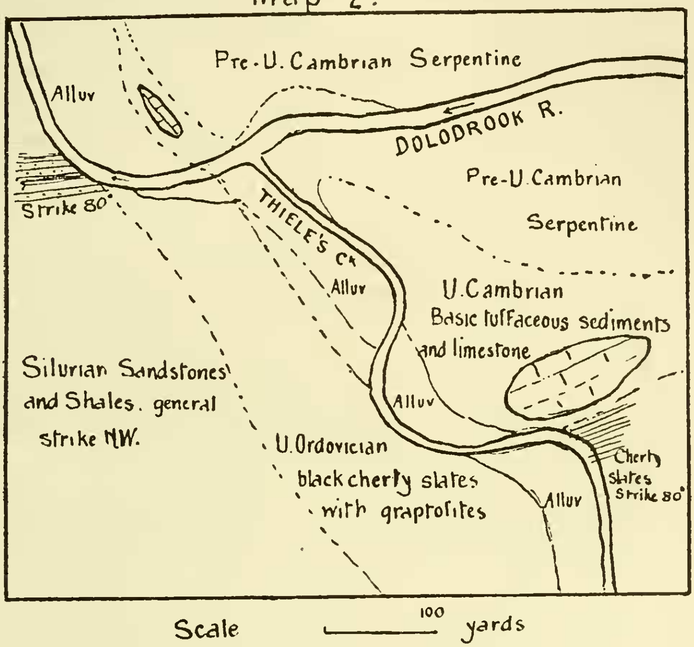
The actual contact of the Cambrian sediments and the Serpentine is shown in the bed of the Dolodrook River, at Thiele's Creek Junction. Here the sediments are of the nature of serpentinous and chloritic conglomerates, grits and finer bands.

A section of this is given by Mr. Dunn (16), who describes the rocks as post-Ordovician, on account of the presence of dense darker rock fragments, which he regarded as Ordovician slate, but which microscopic evidence shows to be a basic igneous rock. The fine dark bands described by Mr. Dunn as slate, prove to be tuffaceous, and similar in character with the basic sediments associated with the Cambrian limestone in every case.

In this vicinity there are two limestone outcrops associated with the basic sediments. Additional thin sections of both the coarse and fine material indicate their tuffaceous character, and support the view also that they belong to the Garvey Gully Series.

The contact and section generally are important, as they show clearly that the Serpentine is a pre-Upper Cambrian rock, the denudation of which in part contributed to the Cambrian sediments.

Map 2.



The remaining portion, consisting largely of diabasic pyroclastic material, indicates an Upper Cambrian volcanic phase.

This section shows also an interesting structural twist in the strike, post-Silurian in age, for the whole series, including the enveloping Ordovician and Silurian rocks, are locally bent round from a north-west strike to one varying between 80° and 100°. This continues for more than a mile easterly, the strike then gradually swinging back to a more normal north-west direction.

Locality C. (Roan Horse Gully).—A traverse from a few chains on the north side of the Dolodrook, opposite the Roan Horse Gully junction, in a S.S.W. direction, across the Dolodrook, and along the bed of Roan Horse Gully, shows well the relative position of the various rocks, and illustrates the typical structure of the inlier.

The limestone is again associated with the same basic sediments, which rest against the south side of the Serpentine. The enveloping Upper Ordovician rocks are found as a very thin belt on the north side of the Serpentine, and repeated just to the south of the limestone. All the strata are highly inclined, being almost vertical, but an overthrust from the north, or north-east, causing a fault in the vicinity of the Ordovician contact, has placed the limestone locally above the graptolite slate, as shown in the sketch section, No. 3. This movement is probably to be correlated with the general overthrust of post-Silurian date, affecting a considerable part of the Dolodrook area, for a fine example of overfolding of the Silurian rock is shown in the Dolodrook, about one mile and a quarter in a straight line below Thiele's Creek junction (Photo. 2).

The Silurian sandstones and shales outcrop at each end of the section forming the next enveloping zone of the complex inlier. The general ge-anticlinal structure is therefore complete along this line.

The Dolodrook Limestones.—These form one of the most important series, for they have provided the definite palaeontological evidence without which it would have been impossible to discover the complete key to the structure of this region.

Previous to resuming the field work in this region, the fossils, chiefly trilobites which Mr. Chapman had definitely concluded to be Cambrian, came from the limestone outcrop No. 1, at the north-west end of the belt.

The first fossil obtained in the district from the limestone, originally regarded by Mr. Chapman as Silurian, came from Roan Horse Gully outcrop, about three and a-half miles to the south-east, but no trilobites had yet been found in this occurrence. The recent field work, however, has been successful in discovering similar trilobites in four separate outcrops, including the Roan Horse Gully limestone, and the mapping generally shows clearly that all the limestone outcrops, of which there are nine, belong to the same series. The additional fossils obtained, Mr. Chapman states, give further convincing evidence of the Cambrian age, and his supplementary palaeontological description will be given later.

Upper Cambrian Fossils.—The following are the fossils described by Mr. Chapman (15) from the Dolodrook :—

Plantae—

Class, Algae. Girvanella Sp.

Animalia—

Class Crinoidea

Crinoid stems, joints and ossicles.

Class Brachiopoda

Lingulella

Orthis (Plectorthis) platystrophioides.

(Originally confused with Platystrophia biforata.)

Class Gasteropoda.

Scenella tenuistriata, Chapman.

Related to Stenotheca—Cambrian of South Australia.

Class Crustacea, Sub. Class Trilobita.

Agnostus australiensis, Chapman.

Ptychoparia thielei, Chapman.

Ptychoparia minima, Chapman.

Crepicephalus etheridgei, Chapman.

The limestone has a pleasing grey colour, is crystalline, and, when polished, would make an attractive ornamental stone, but in its present inaccessible position there is no immediate prospect of it being available for use. No quantitative analysis of its composition has been made, but a qualitative test showed that it was relatively pure, with only a small percentage of magnesium carbonate. All the outcrops are of lenticular character and small extent, the two largest being No. 1 Dolodrook, and that at Roan Horse Gully. The latter can be traced along the strike for about three hundred yards, and shows a good face towards Roan Horse Gully of about a chain in width.

Upper Ordovician.—These rocks, consisting of black slates, with highly cherty bands frequently intensely contorted, have been referred to in a previous paper (13), but their extent and relationship to the other rocks in the vicinity had not been fully traced. It had been recognised in general that they wrapped round the central inlier of Serpentine and associated rocks, but the outer boundary had not been followed. The result of additional field work makes it now possible to indicate these features on the map presented; showing that the Ordovician rocks are in turn enveloped by an outer ring of later sediments, with a distinct lithological and palaeontological break. The slates are everywhere readily distinguished in the field from the less indurated shales and sandstones of the next series. Graptolites are abundant throughout even in the most highly cherty representatives, but naturally the best preserved specimens are obtained from the less altered bands. The forms represented are uniformly Upper Ordovician types. The first graptolites were obtained by the writer in 1905, and were described by the late Dr. T. S. Hall (14). Since then other forms have been collected from various parts of this area, and numerous other collections have been made by various members of the geological survey throughout Eastern Victoria.

Of these occurrences, the best collections have come from (1) Matlock, (2) the Thomson-Jordan Valley, (3) the Black River Belt, and (4) the Wellington area. These four localities consist of parallel strips of Upper Ordovician rock, separated by belts of Silurian sandstone and shale. The fossils show that these outcrops, if not identical in horizon, are at any rate, very closely allied; and owe their reappearance to successive intense folding along lines of N.N.W. axes, resulting also in the folding of the overlying Silurian rocks in a similar way. Subsequent denudation during the present cycle of erosion has exposed some Ordovician as inliers. They are generally narrow, elliptical belts, conforming to the general strike, but disappearing along the strike under the Silurian, often to reappear, however, at varying intervals along this line. This is due mainly to a very general development of pitch, sometimes north and sometimes south. This structure, common throughout the older rocks of Victoria, has been clearly brought out in the Wood's Point and Walhalla district by the excellent field work of Mr. O. A. L. Whitelaw and Mr. W. Baragwanath respectively.

Up to the present no definite graptolite zones have been recognised in the Upper Ordovician in Victoria. It is probable that the vertical range in the Upper Ordovician is not so great, but it is likely that systemate work would yield some definite results in favourable areas.

The following is the complete list of graptolites recorded from the Wellington region :—

Diplograptus foliaceus, Murchison.
Diplograptus thielei, T. S. Hall.
Diplograptus (Orthograptus) quadrimucronatus, J. Hall.
Diplograptus (Orthograptus) calcaratus, Lapworth.
Leptograptus flaccidus, J. Hall.
Climacograptus wellingtonensis, T. S. Hall.
Climacograptus bicornis, J. Hall.
Climacograptus bicornis, var. tridentatus, Lapworth.
Climacograptus tubuliferus, Lapworth.
Dicellograptus elegans, Carruthers.
Dicellograptus morrisi, Hopkins.
Dicellograptus gurleyi, Lapworth.
Cryptograptus tricornis, Carruthers.

Dicranograptus nicholsoni, Hopkinson.
Dicranograptus hians, T. S. Hall.
Nemagraptus gracilis, J. Hall.
Lasiograptus margaritatus, T. S. Hall.

Most of the above species are widespread and abundant in their occurrence throughout the area, but Orthograptus calcaratus has only been found at one spot in the north-western extremity of the Ordovician, marked G, where it is associated with abundant Climacograptus bicornis and another rare form, C. tridentatus. The last-named species was also found at another locality, marked $G._2$.

Splendidly preserved specimens were obtained, and it is the first undoubted record for Victoria, a doubtful instance has been recorded from Cravensville.

Nemagraptus gracilis has only been found in Roan Horse Gully.

Dicellograptus gurleyi is also rare, and has only been recorded from the Wellington area.

See comparative table, showing general record of Ordovician graptolites in Victoria.

It is interesting to note that a small amount of turquoise was observed in several places, chiefly as very thin veinlets in the joints of the cherty rocks and, occasionally, also associated with white quartz.

The mineral is evidently widespread in its occurrence in the Upper Ordovician rocks in Victoria. The best known localities are Ryan's Creek, Myrrhee (31), and Mt. Avis, Edi, King Valley, Mr. Caldwell tells me that he found it in black slate on the Black River, and I found it myself in light-coloured chert in the Tara Range.

A certain amount of white powdery phosphatic material also occurs irregularly distributed along joints and fractures. One sample of altered siliceous rock yielded an analysis 8% of P_2O_5.

Some phosphatic deposits of promise from an economic standpoint occur in the vicinity of Mansfield. They are associated with Ordovician rocks, but their true relation is still the subject of controversy.

The cherty nature of the Ordovician rocks of the Wellington district is a noteworthy feature. The prevailing colour is black, and the most completely altered bands are of the nature of lydianite or black jasper. All grades of silicification occur, and though in general the cherts run in bands with intervening belts of more normal slate, instances are common showing slightly chertified slate a few inches wide between beds of jasper. There has clearly been a selective action in the process of silicification, probably controlled mainly by primary differences in composition existing in the original strata. Thin sections, however, of the slates and cherts have so far not revealed what these differences were.

The alteration is not attributable to the direct contact action of igneous intrusion, but would appear to be explained by a selective metasomatic replacement due to aqueous solutions permeating the rock.

Instances of this type of chertification are found throughout the Palaeozoic rocks. It is natural, therefore, to find cherts of very different ages resembling each other somewhat closely, and this has led to considerable confusion on account of some geologists having correlated numerous cherty outcrops with the "Heathcotian" on purely lithological grounds.

Professor Skeats (18) has discussed the origin and occurrence of the cherts of the Heathcote area, and has shown that they are largely due to metasomatic replacement of diabase and diabase tuffs. The age is left an open question, but their inclusion in the basal portion of the Ordovician was favoured on the then known palaeontological evidence.

Dr. Summers (21) has described cherts and associated rocks at Tatong, where they are interbedded with fairly normal sediments, which he regards as Upper Ordovician.

In the Wellington area and in the Tara Range, near Buchan, I have found Upper Ordovician graptolites actually in the cherts. It is therefore clear, as Dr. Summers points out, that the occurrence of cherts as characteristic of the Heathcotian Series loses its significance.

Up to the present no radiolaria have been noted in thin sections of the Wellington cherts which have been examined.

Reviewing the important structural points brought out by a study of the Lower Palaeozoic geology of the Wellington area, it is clear that the axis of this complex inlier marks an important structural line, the direction of which is parallel with the main Palaeozoic trend lines, along which a succession of important tectonic movements have been renewed many times. We therefore find the zonal arrangement of successive formations bearing in a prevailing N.N.W. to N.W. direction very marked, exposing in this case within a remarkably small area, narrow, parallel but unconformable belts from Cambrian to Silurian.

With this in mind, it is natural to look expectantly along the continuation of the strike of this belt.

Upper Ordovician Graptolites.

	Mt Wellington District. E.D.T.	Turquoise Mine, Ryan's Ck. Myrrhee (A.M.H.)	" " Mt Avis, Edi (A.M.H.)	North slope, Mt Easton, 3 miles from Thomson-Jordan Junc. (W. Bd)	Dingo Ck, 290° 2 mls Thomson-Jordan Junc. (W. Bd)	Main Divide between Mt Selma and Spring Hill. O.A.L.W.	Black R, near junction with Ten Mile Ck.	Two miles NW. of Mt Easton.	Three quarters of a mile NE of Mt Easton.	Matlock 1½ mls. SW Kelly's Hill. E.O.T. and Geol Surv.	Sandy's Creek Mitchell R.	Cravensville.	Dark R.	Tungamah.	Snowy R, Mt Deddick.	Accommodation Ck. Deddick.	Walwa Ck.	Wombat Ck.	Mt Deddick. (river pebbles)	Cabandindra.	Thoona.	Mt Laughlan's Ck.	Two miles east of Myrtleford. E.J.D.	Kerrie ? U. Ordovician	Myrtleford, loch. N.E. Allot. 2 (W. Clemens)	Nomo Nomo. O.A.L.W.	Tara Range. E.O.T.	Parish of Newham, Sec V.A. E.W.S. & H.S.S.	S. of U. Macedon, Loc. 51	Emu Creek, Allot 48A Kerrie	Kevington O.A.L.W.	Jordan R, 2½ miles above Jericho O.A.L.W.
Diplograptus sp.	⊕	⊕	⊕		⊕	⊕	⊕																					⊕	⊕		⊕	
D. cf *tamariscus*, Nicholson										+																						
D. foliaceus Murchison.	+			+	+		?		+	+		+				+			+		?									+		
D. thielei, T.S. Hall.	+																															
D. carnei, T.S. Hall.								+									+	?				?										
D. ingens, T.S. Hall									+	..																						
D. pristis																		?														
D. cf *aculeatus*, Lapworth									+																							
D. (*Orthograptus*) *quadrimucronatus*, J. Hall	+								+																							
D. " *angustifolius*, J. Hall.																										+						
D. " *tardus*, T.S. Hall.																																+
D. " *calcaratus*, Lapworth.	+															+																+
Leptograptus sp.																															⊕	
L. flaccidus, J. Hall.	+							+	+																							
Climacograptus sp.			⊕	⊕	⊕		⊕	⊕																⊕		⊕	⊕					
C. wellingtonensis, T.S. Hall.	+																															
C. bicornis, J. Hall.	+			+					+			+							+													+
C. bicornis, var *peltifer*, Lapworth.																																+
C. tridentatus, Lapworth.	+											?																				
C. baragwanathi, T.S. Hall.									+																							
C. hastatus, T.S. Hall.										+																						
C. tubuliferus, Lapworth.	+			+						+							+			?												
C. cf. *innotatus*, Nicholson.										+																						
C. caudatus, Lapworth.																+																
C. mensoris, T.S. Hall.								+																								
Dicellograptus sp.								⊕				⊕					⊕		⊕				⊕								⊕	
D. affinis, T.S. Hall.				+	+					+									+													
D. elegans, Carruthers.	+			+					+									+		?										+		+
D. morrisi, Hopkinson.	+									+										+												
D. gurleyi, Lapworth.	+																															
D. cf *anceps*.																		+				?										
D. sextans, J. Hall.																																+
D. complanatus, Lapworth var. *ornatus*, Ellis and Wood								+																								
D. aff *forchammeri*, Geinitz.					+																											
Cryptograptus tricornis, Carruthers.	+								+							+																+
Dicranograptus sp.							⊕																								?	
D. nicholsoni, Hopkinson.	+								+																							
D. hians, T.S. Hall.	+								+							+																
D. ramosus, J. Hall.									+		+			+	+																	+
D. var. *semispinifer* T.S. Hall.																?																
D. var *longicaulis* T.S.H.																										?						+
D. furcatus, J. Hall.																																+
Nemagraptus gracilis	+																															
Lasiograptus margaritatus, T.S.H.	+			⊕				+	+																							
Glossograptus sp.	⊕		⊕	⊕					⊕																		⊕				⊕	
G. fergusoni, T.S. Hall.				+																												
G. hermani, T.S. Hall.		+	+								+	+	+	+							?					+						?
Clathograptus geinitzianus, J. Hall.																										+						
Dendrograptus sp		⊕							?	?																						
Didymograptus cf *caduceus*, Salter.			⊕		⊕									+												+		?				
D. ovatus T.S. Hall											+																					
Dichograptus sp			⊕																						⊕	⊕						

Note. – ⊕ indicates that the genus only has been recorded.

It may be of some significance, therefore, that we find in this line other complex Lower Palaeozoic inliers, whose structural details and relationships are still a subject of controversy, and provide promising scope for further work.

The phosphatic deposits at Flannery's, near Mansfield, and the associated sedimentary rocks form one of the most interesting inliers in question.

Some very fragmentary fossils were obtained some years ago from the phosphatic material, consisting chiefly of Salterella, and obscure trilobite remains. The fossils were very unsatisfactory, but were regarded by Professor Gregory as probably Cambrian. Professor Skeats and Dr. Summers have obtained both Upper and Lower Ordovician, and Mr. A. M. Howitt Lower Ordovician graptolites in such close proximity to the spot from which the trilobite remains were found that the geology is clearly complex, and the results of more detailed work should be of considerable interest.

Another area requiring further attention is in the Upper Howqua Valley, at such a position that the extension of the Cambrian axis of the Wellington region might be expected to appear.

Mr. A. M. Howitt (22) made a flying visit to this region about eleven years ago, and recorded the occurrence of cherts, which were regarded as Cambrian, phosphate rock, amphibolites and serpentine of undetermined age, also Silurian slates and sandstones.

The relationship of these rocks has recently been discussed by the author in the Proc. Roy. Soc., Vic.

Silurian.—The rocks of this series consist chiefly of alternating quartzitic sandstones and greenish sandy shales. Some of the latter have a marked rubbly to splintery mode of weathering, and by oxidation are frequently rusty brown near the surface. They dip at high angles, and have been folded along numerous axial lines in a general N.N.W. to N.W. direction. Though they have been subjected to much folding and even overfolding, as shown in the Dolodrook, below Thiele's Creek junction (Photo. 2), the intense contortion which is such a marked feature of the Ordovician is as a rule absent.

The actual contact between the Ordovician black slates can be seen at several outcrops. Three of these are worthy of mention. One is in Blyth's Gully (Loc. D.), about 20 chains N.N.W. from the Wellington-Dolodrook Junction. Another is in the bed of a steep tributary gully of the Wellington, about a mile N.W. of the abovenamed junction (Loc. E.), and the third is in Thiele's Creek, about

30 chains south from its junction with the Dolodrook (Loc. F.). In all these instances, conformity of strike and similarity of dip are shown, but the horizontal extent of the exposure is limited, and when the general boundaries of the contiguous formations are traced the evidence in favour of an unconformity is more marked. The lithological break is a sharp one in every case, and the graptolites are abundant in the slates to the junction when they stop suddenly.

Unfortunately, no distinctive fossils definitely recognisable as Silurian were obtained, but a grit containing crinoid impressions was noted at Locality D, and a similar crinoid bearing grit was noted in the Dolodrook valley close to the outer boundary of the Ordovician, confirming the ge-anticlinal interpretation of the structure.

Mr. Chapman states that the material, though not conclusive, is lithologically similar to fossiliferous grits of Silurian age collected by Mr. Whitelaw in the Wood's Point Belt, where they bear a similar relation to the underlying slates.

This series is of great extent, wrapping round the Ordovician and older rocks, and forming a wide area of hill country.

From its furthest limit, in the north of the Carey River, where it disappears under the Upper Palaeozoic rocks, southwards to the vicinity of Glenmaggie, where it passes under the Tertiary plains, is a distance of more than thirty miles in a straight line.

It is the outer zone or ring of the complex Lower Palaeozoic inlier and the Upper Palaeozoic cover is found continuously along its eastern limits, approximating to the Avon watershed.

On the west denudation has been more effective, so that the Upper Palaeozoic over-mass is wanting between Hickey's Creek and the plains, a distance of about twelve miles.

The rocks, therefore, regarded as Silurian, can thus be traced continuously to the Macallister Valley to the south of Hickey's Creek, and thence westerly to the Wood's Point-Walhalla zone, included in the surveys of Messrs. Whitelaw and Baragwanath, respectively.

Within the area mapped several of the prominent elevated points rising to well over 3000 feet, are due to the superior resistance to weathering of some of the hard quartzitic sandstone of this series. The three most conspicuous and noteworthy are Mts. Hump, Margaret and Ronald.

Upper Palaeozoic.—The rocks here considered form a portion of the most extensive occurrence of this age found in Victoria. The extent of the whole belt from its southern border, where it is contiguous with the Gippsland plains to the northern limit toward Benalla, is about 100 miles, and the greatest width is about forty miles. The general trend of the belt is about N.N.W. It is composed in part of sedimentary rocks, consisting chiefly of thick conglomerates, coarse sandstone and chocolate shales and mudstones, with in places interbedded acid and basic lava flows. The sedimentary series in the vicinity of Mansfield contains fossil fish of Lower Carboniferous types, associated with Lepidodendron.

The strata of the southern portion are very similar lithologically to those of the Mansfield area, but with the exception of an imperfect fish scale, the only fossils obtained were those of Lepidodendron, found in widely separated localities in the Macallister valley, and also that of the Avon. The Geological Survey Map shows this series as Upper Devonian, and the Mansfield region as Carboniferous, but the evidence in favour of their separation is inconclusive, and they are here all regarded tentatively as Lower Carboniferous.

In addition to the above group of rocks, there is a great development in the northern portion of the belt, and particularly in the valley of the King River, of acid porphyritic rocks, which, according to Professor Skeats (28), appear to be related to the dacites, suggesting their correlation with the dacites of the Strathbogies and elsewhere, which are generally regarded as of Lower Devonian age. This is in conformity also with the field evidence of A. E. Kitson (10), who interprets them as being uncomformably overlaid by the Upper Palaeozoic sediments.

Along the western margin of the Upper Palaeozoic belt is the Barkly Valley, notably on Fullarton's Spur. O. A. L. Whitelaw shows in his map the occurrence of porphyritic rocks, some of which Professor Skeats has recognised as altered andesites, distinct from the acid lavas of the Wellington area, and comparable most probably with some of the Lower Devonian volcanics, typically known as the "Snowy River Porphyries."

Another interesting feature is brought out by a study of the geological map of Victoria, with reference to the eastern and western adjoining formations. On the eastern side the older rocks are Upper Ordovician; no Silurian has yet been recognised.

To the west, and continuing to the vicinity of the meridian of Melbourne, Silurian rocks, prevail, with only relatively narrow inliers of Upper Ordovician.

Should more detailed work later fail to discover any Silurian rocks to the east of the Upper Palaeozoic belt, it would seem to point to the possibility of an old eastern shore line of the Silurian sea, which is now buried beneath the latter rocks of this area.

The whole Palaeozoic history of this belt, with its succession of sedimentary and volcanic events emphasises that it has represented a major tectonic and structural zone throughout Palaeozoic times.

The two areas where the Upper Palaeozoic rocks have received most attention from me are the vicinity of Mt. Wellington and the Macallister valley, at Hickey's Creek. These two areas will be considered separately.

Wellington Area.—The position and extent of these rocks within the area discussed is shown on the map, and their relationship to the underlying rocks is indicated in sections, numbered 1, 2, 3 and 4. It will be seen that they rest unconformably on the Silurian and older rocks, and in general the beds dip at low angles with a marked absence of the sharp repeated folds of the older series.

On the western side of the map it is seen that the beds dip uniformly westerly (W.S.W.), and on the Wellington side the dip is easterly. These two directions have been proved to form part of a large anticlinal fold at least fifteen to twenty miles in width. The axis has a direction of about N.N.W. and lies between Mt. Tamboritha and Mt. Wellington. The southern portion has suffered much denudation, with the result that within the area examined, the crown of the fold has entirely gone, revealing the underlying older rocks, which have, in turn, been much dissected during the present cycle of erosion. The two limbs of the folds are preserved with their steep scarp slopes opposing one another, forming, especially in the case of Mt. Wellington, bold and precipitous cliffs. (Photo. 3.)

The rock succession is very constant over the whole area, though the thickness of the individual beds is subject to some variation, and in general the observations of Murray (9) and Howitt (4) in other portions of this region, indicate the same succession and features.

The basal beds almost everywhere consist of reddish conglomerates, breccias, or breccio-conglomerates, with pebbly sandstone and red shaly bands developed locally. The pebbles and boulders consist chiefly of quartz and quartzite, with some indurated shale and cherty slate.

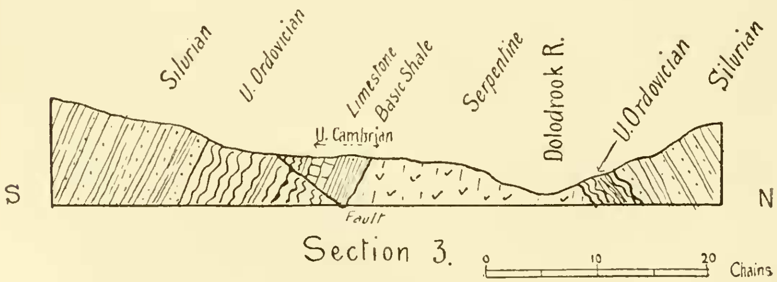
One feature of importance is the occurrence also of acid igneous fragments and boulders. Some of these are exactly similar to the rhyolites and rhyolitic porphyries of the Wellington series which overlie these beds. Others are too decomposed for definite comparison.

No outcrop of Lower Devonian igneous rock has been recognised in the area, but as indicated previously rocks probably of this age occur about ten miles to the N.N.W. at Fullarton's Spur and about forty miles to the N.N.W. in the King River District.

From a comparative microscopic examination of numerous thin sections of Lower Devonian porphyries with those from the Wellington area, the details of which will be given later, it appears probable that a satisfactory distinction may be made microscopically between the two series.

If this feature is proved by wider investigation to enable a generalisation to be made, it may be possible to recognise in these conglomerates and breccias, porphyries of two distinct periods representing material derived from a Lower Devonian source, and also later rocks belonging to the first products of the outbreak of the Lower Carboniferous volcanic activity.

A considerable thickness of acid lavas and tuffs succeeds these basal beds over wide areas, and it seems likely that though the main outburst and effusion slightly succeeded the deposition of the conglomerates, some of the earliest outbursts were practically contemporaneous, contributing some of the admixed igneous material which suggests the nature of volcanic ejectamenta.



Section 3.
Roan Horse Gully

One of the best sections showing the basal beds where the breccia character predominates is at Locality G, Wellington River, about three-quarters of a mile below the Wellington-Dolodrook junction. The beds are of a coarse nature, and contain both angular and water-worn rocks, consisting largely of black cherty slates, quartzites and quartz; stratification is visible, and the beds are here inclined at a much higher angle than usual, dipping to the W.S.W. at about 70°. They are seen to rest against the Upper Ordovician cherty slates, which are much contorted, and the junction suggests a fault line, striking north-westerly. The same beds show a marked discordance in strike at another outcrop, about fifteen chains to the north-west, where there appears to be a short north and south fault. The strike on one side is about N.E., and on the other N.W .

The belt as a whole, however, is traceable almost continuously without any noteworthy break, below the overlying rhyolite sheet, and these disturbances in dip and strike, though striking, are only of limited extent.

Another deposit with some special features is exposed in the bed of the Wellington River, still further to the north-west at Locality H. Its exact nature and relationship is not clearly understood, but it may be an extreme lithological variation of the basal beds under discussion. The extent is about 20 chains over about a width of one chain along the bed of the river.

Its character is that of a coarsely fragmental deposit, composed very largely of fine grained diabasic rock, the interstices being filled up with granular quartz and calcite. A few angular inclusions of quartz porphyry similar to that of the Wellington series were noted.

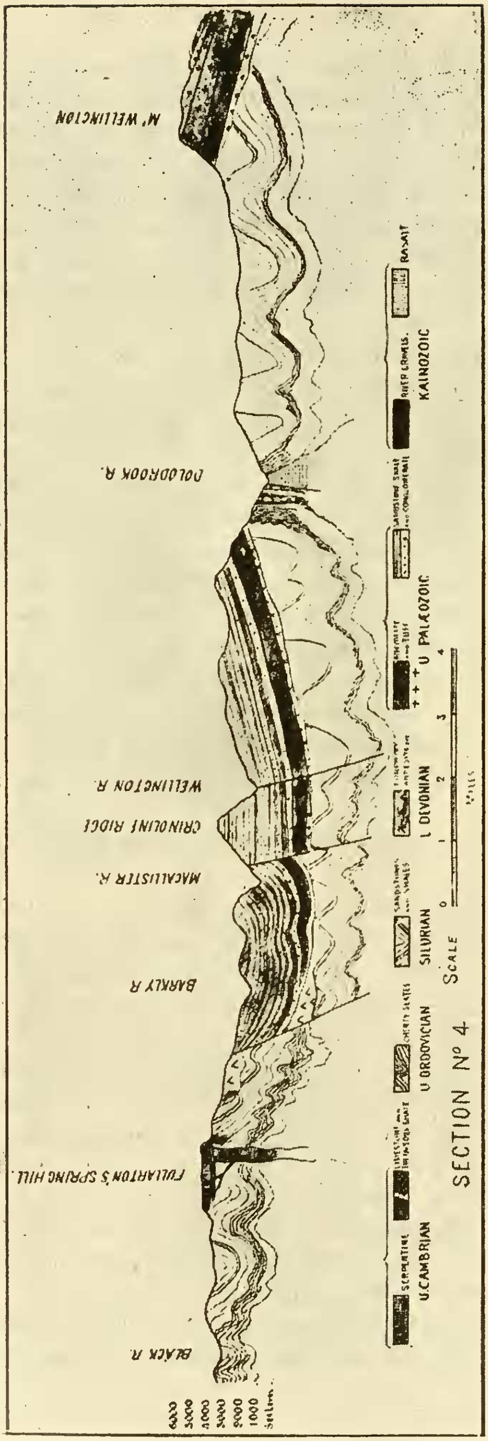
A number of thin sections from various parts of this deposit were examined.

The diabasic material is fine grained, and much altered. Fine plagioclase laths and magnetite are recognisable, but there is much chlorite and calcite. The interstitial material is siliceous and calcareous, consisting of a coarse to fine grained mosaic of quartz and calcite.

Secondary silicification affecting both the diabase and the interstitial material is recognisable, but an original fragmental character can be recognised in some sections, showing altered fragments of shale and diabase, irregular grains of quartz, showing secondary growth and an occasional fragment of orthoclase.

The porphyry inclusion shows a fine microcrystalline siliceous base, with corroded and embayed orthoclase phenocrysts, showing some kaolinization and secondary silicification.

These acid igneous inclusions suggest possibly a Lower Carboniferous source, and though the relationship of the deposit to the


M
M' WELLINGTON
DOLODROOK R.
WELLINGTON R.
CRINOLINE RIDGE
MACALLISTER R.
BARKLY R
FULLARTON'S SPRING HILL
BLACK R.
SERPENTINE
U.CAMBRIAN
CHERTY SLATES
U ORDOVICIAN
SILURIAN
L DEVONIAN
U PALAEOZOIC
RIVER GRAVELS
BASALT
KAINOZOIC
SCALE
SECTION No 4

surrounding rocks is not clear, the occurrence is included tentatively with the basal beds of the Upper Palaeozoic.

The Rhyolites and Associated Tuffs.—These rocks occur as a well-defined sheet of great extent. They are readily traced in the field, consistently near the base of the series along either limb of the main anticlinal fold. They vary in thickness from less than 1000 to over 2000 feet. In the thinnest portions they would appear to represent a single flow, but in Mt. Wellington where they form a bold escarpment on the western face, they are composed of successive beds of pyroclastic material and rhyolitic flows.

These rocks, under the name of quartz-porphyries and felsites, were recognised by Howitt and Murray, in widely separated areas in this region, and they were invariably found occupying a position towards the base of the series. Howitt recognised the volcanic nature of the rock, and that there were both effusive and pyroclastic representatives. One of the finest sections, that of Snowy Bluff in the Moroka Valley, to the north of Wellington, has been carefully described by both Murray (9) and Howitt (4).

The rhyolitic rocks there rest on conglomerates, and are estimated at about 100 feet in thickness. One of the striking features of much of the igneous material in the vicinity of Wellington is that rocks of the outward appearance of quartz-porphyries, are often crowded with water-worn pebbles of quartz and quartzite, often producing quite a conglomeratic appearance. Numerous inclusions of indurated slate and shale are also common.

Thin sections of some of these rocks have shown that the igneous material of which they are in part composed, is pyroclastic. One particularly fine example from the northern shore of Lake Karng, Mt. Wellington, showed the tuff character remarkably well (microphoto.). It contains angular and broken fragments of quartz and felspar set at all angles in a fine microcrystalline base, containing beautifully preserved tubes of irregular outline so characteristic of tuffs, but seldom so well preserved. Their bent and twisted shapes and broken cusp-like forms are particularly striking in the section.

The fact that material of this nature is often admixed with waterworn pebbles of the old rocks, points to the conclusion that explosive volcanic action was practically contemporaneous with the deposition of part at any rate of the basal conglomerate beds.

Another section from the southern shore of the lake has been referred to in a previous paper (13). It has the character of a rapidly-cooled lava and shows very fine perlitic structure.

The rock on the summit of the plateau is a typical banded rhyolite, the flow lines being very conspicuous.

The detailed succession of igneous material building up the Wellington mass has not been worked out, but there is a noteworthy thickening in the vicinity of Lake Karng. In the southern bluff of Wellington the thickness is not more than 1,000 feet, but in the vicinity of the Lake it is more than double that amount. This is probably accounted for mainly by the presence of marked irregularities of the Palaeozoic surface on which the volcanic beds were laid down.

It is perhaps strange that no undoubted vent or fissure by which the volcanic material reached the surface, has yet been definitely recognised, nor have any dykes, acid or basic, been noted in this region. Considering the high melting point of rhyolite, its viscous nature, the deep dissection of the rocks, and the wide extent of the lava flows in this region, it is perhaps remarkable that some channel by which it reached the surface has not yet been recognised.

No undoubted intrusive quartz-porphyries have yet been noted in this region.

A fine section of the rhyolite, showing its relations to the basal conglomerates and over-lying sandstones, is shown in the course of the Wellington, just north of Shaw's Gap, or one mile and three-quarters in a straight line north-west from the Wellington Dolodrook junction. (Loc. 1.) Here the river has cut a tortuous canyon for about half-a-mile through the rhyolite, forming precipitous cliffs, showing fine columnar structure. (Photo. 4.)

The remaining portion of the series, amounting to some thousands of feet in thickness, consists largely of alternating beds of conglomerate, passing into pebbly sandstone and normal gritty sandstone, separated by beds of varying thickness, of purple shales and mudstones, with, in places, interbedded sheets of altered basalt. (Melaphyre of Howitt.)

Fossils are rare throughout the series. The first obtained came from the sandstones of the Avon River, and were described by Sir Frederick McCoy as Lepidodendron Australe. The writer has since noted Lepidodendron at four localities in the Macallister basin. They are as follow :—

(1) Roadside cutting near Basin Flat.
(2) Roadside cutting, Macallister R.—Target Cr. Junction.
(3) Reid's Selection, near Barkly R.
(4) Near Glencairn (Mr. Sweetapple's).

The only other fossil obtained was a fish scale, from near the Wellington-Dolodrook junction, regarded by Mr. Chapman as probably belonging to the rhizodont genus Strepsodus (23)

The general nature of the beds, together with the contained fossils, indicate a freshwater or lacustrine origin, and the shape of the basin appears to have been that of a long relatively narrow trough, at least a hundred miles in length, with a general N.N.W. direction.

The Melaphyres.—These have been referred to briefly in a former paper (13), and two analyses by G. Ampt were included. Reference is also made to Howitt's description of the melaphyres of Snowy Bluff, where at least eight distinct flows separated by beds of sandstone and shale have been recognised, but they are never of any great thickness (7).

Until last year, no melaphyre had been noted within the area under consideration, but one occurrence can now be recorded in Wallaby Gully, towards its head.

The section forms a small fall in the channel of the creek, showing a bed of melaphyre twelve feet thick resting on red shaly mudstones, with a thin band of mudstone on top followed by sandstone. The flow is distinctly amygdaloidal at the top and bottom with the usual secondary quartz, calcite and epidote. The central portion is a dense fine grained rock. A thin section of this shows under the microscope a distinct flow structure due to the parallel arrangement of the felspar laths. These have a low extinction angle, and appear to be oligoclase; they are ophitically enclosed in chlorite into which all the augite has passed. Analyses of this rock are not very satisfactory on account of the great amount of alteration which has taken place. The one here submitted is from the central portion. The low amount of lime and magnesia is probably due to secondary leaching, for calcite amygdales are common in the upper and lower portion and thin sections of these parts also show calcite.

For comparison the two analyses by Ampt of samples from the basin of the Moroka are repeated. No. 2 was the freshest sample and, therefore, probably the most normal.

The Melaphyres are clearly subaqueous basic lava flows, and are always found considerably higher in the series than the Wellington Rhyolites.

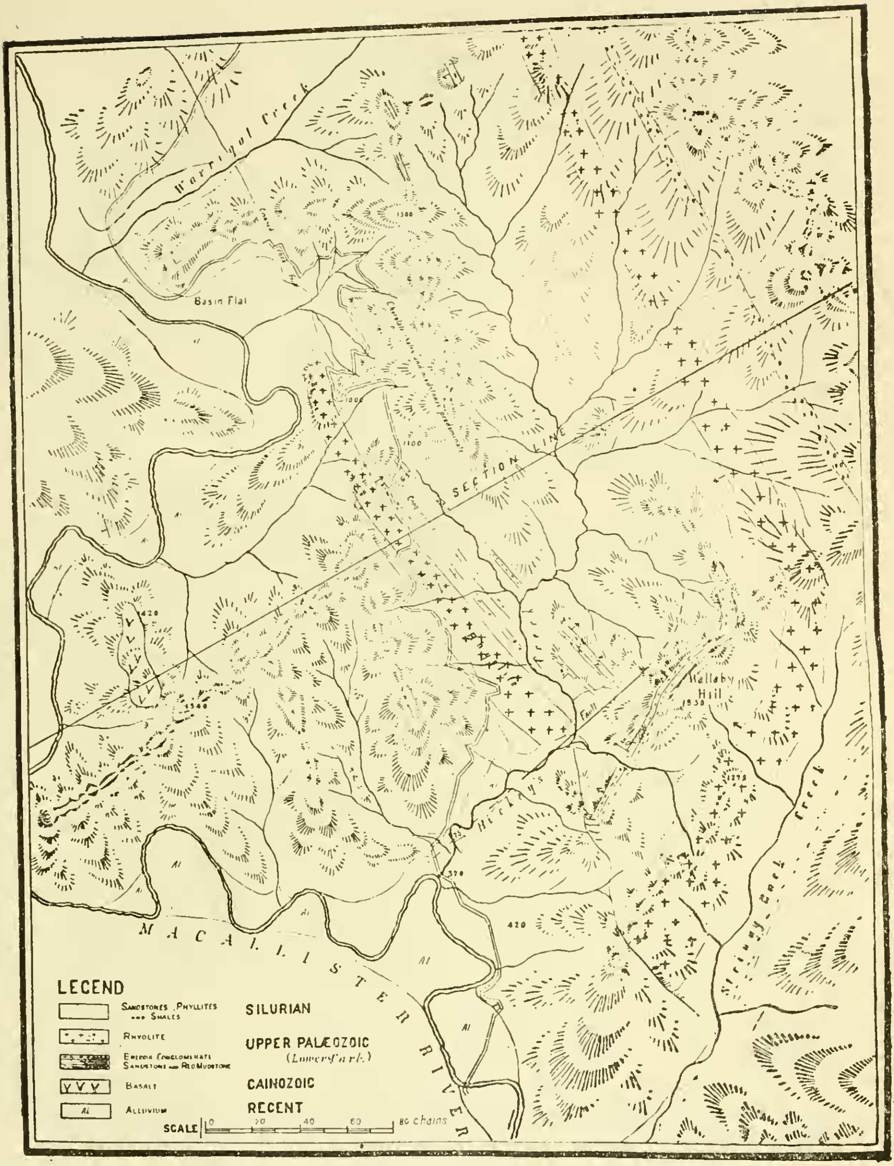
	1	2	3
SiO_2	47.84	49.35	43.88
Al_2O_3	16.17	17.61	16.58
Fe_2O_3	9.28	1.50	5.83
FeO	8.64	9.72	9.11
CaO	4.70	7.71	9.60
MgO	2.62	3.17	5.77
Na_2O	4.47	3.10	2.02
K_2O	0.08	1.56	1.06
P_2O_5	tr.	tr.	tr.
H_2O	0.06	0.65	0.64
H_2O	2.51	2.56	2.22
TiO_2	2.68	2.83	3.52
MnO	0.30	0.07	tr.
Pyrite FeS_2	—	0.34	
	99.35	100.17	100.23
S.G.	2.82	S.G. 2.918	

1. Melaphyre (No. 177), Wallaby Creek, Wellington Valley. —Analyst E. O. Thiele.
2. Melaphyre, Moroka Snow Plain; fairly fresh sample. —Analyst G. Ampt.
3. Melaphyre, Bad Spur, Moroka Valley; altered specimen. —Analyst G. Ampt.

HICKEY'S CREEK DISTRICT.

This is a relatively small area on the eastern side of the Macallister valley, at Hickey's Creek junction, about twelve miles from Glenmaggie (see Map 3). It lies on the route from Heyfield to Mount Wellington, via the Macallister Valley, and therefore had been frequently traversed during the journeys to and from the Wellington region.

Here particularly, as well as at other points further north in the Macallister Valley, the Upper Palaeozoic rocks had been noted to be very highly inclined, with dips ranging up to nearly vertical, and sometimes in the reverse direction to the normal one. It was therefore decided to give a little time to a more detailed study of the features, with the result that some interesting structural points are brought out, marking a powerful tectonic line running approximately N.N.W., and probably continuing for a great distance in this direction, coinciding very closely with the western boundary of the Upper Palaeozoic series. A new road for vehicular traffic in place of the old pack track has recently been made as far as the junction of Target Creek with the Macallister, about thirty miles from Glenmaggie. At Hickey's Creek, this road leaves for a time



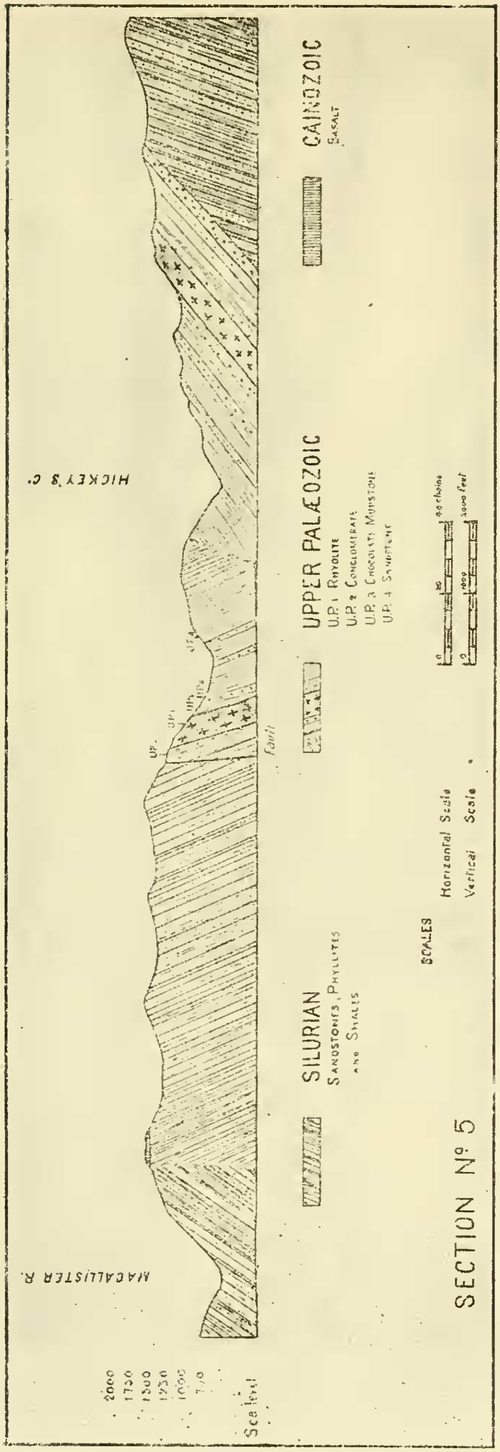
MAP No. 3

the Macallister, and rises by a long sidling grade more or less parallel with the valley of the creek to a saddle, thence descending to the Macallister again at Basin Flat by a similar winding grade cut out of the steep hillside. This part of the road affords a succession of fine sections of the highly inclined Upper Palaeozoic rocks, including the basal beds, rhyolite, conglomerates, sandstones (in one place containing Lepidodendron), purplish shales and mudstones. The area mapped includes this part of the road, and the Hickey's Creek Basin essentially, most attention being given to the Upper Palaeozoic rocks, and their contact with the older rocks. The only other formations noted are the Silurian sandstones, phyllites and shales, and a small remnant of a Kainozoic basalt flow.

Silurian.—The usual alternation of quartzitic sandstones with phyllites and shales is found in this area, but the phyllites and shales predominate over the sandstones. They are generally greenish in colour, due to a certain amount of chlorite, and are fairly arenaceous. The whole series is intensely folded and frequently crushed. Small quartz veins are very abundant either along joints, shear planes, bedding planes, or fracture lines.

Upper Palaeozoic.—The rocks belonging to this series are identical in character and succession with those described in the Wellington area, but their high angle of inclination is a striking feature.

The prevalence of thick beds of conglomerates, and coarse pebbly sandstone, and the general red colour of most of the beds, especially the shales, combine to form a striking contrast with the Silurian rocks. The boundaries as a rule are, therefore, readily traced in the field, and also certain characteristic beds within the series can be easily followed for considerable distances, and these are of great assistance in working out the structure. In this way the rhyolite and associated conglomerates were found in following across the strike to be repeated on account of a marked synclinal structure, but as the mapping shows it is not of a simple character, for one limb is bent round in such a manner in the vicinity of Wallaby Hill as to bring the strike of similar beds at right angles. This point is perhaps the most striking feature in this area, for it forms a precipitous rocky crag rising on the eastern side of Hickey's Creek. It is composed of beds of coarse conglomerates dipping at 50 degrees to the N.W. and striking N.E. The beds are cut through towards the southern end by a small tributary of Hickey's Creek causing a rocky cleft, which isolates another rocky crag of slightly lower elevation, and composed of the same conglomerate. Following these beds along the strike in a N.E. direction, they soon swing round to N.N.W., and the same feature is noted with regard to the underlying rhyolite and basal conglomerate. The same rhyolite and conglomerate can be noted on the western side of Hickey's Creek, dipping in the opposite


CAINOZOIC
BASALT
UPPER PALÆOZOIC
U.P.1 RHYOLITE
U.P.2 CONGLOMERATE
U.P.4 SANDSTONE
SILURIAN
SANDSTONES, PHYLLITES AND SHALES
SCALES
Horizontal Scale
Vertical Scale
SECTION No. 5
HICKEY'S C.
MACALLISTER R.
Sea level
fault

direction at a high angle. Fine sections are shown in the road cuttings, about two miles northerly from Hickey's Creek junction (see 12). From about this point, also looking south-easterly across the deep valley of Hickey's Creek, there is an interesting view of Wallaby Hill, showing on the upper portion bare dip faces of the conglomerate striking at right angles to the direction of view. At the same time, in the lower slopes, there are conspicuous outstanding ribs of conglomerate and sandstone dipping at a high angle to the north-east, and whose strike therefore is at right angles to the rocky face forming the summit.

Faults.—Reference to Map 3 and Section 5 of this area shows that an intense compressional movement at right angles to a N.N.W. axis has nipped in and folded a belt of the Upper Palaeozoic sediments in a trough of older rocks. Along the western contact, at several places, the rocks are disturbed and often much crushed. A fine example of crushed rock is seen in Hickey's Creek, close to the old pack track, and about three-quarters of a mile from the Macallister junction. Here a portion outcrops as a conspicuous monolith, about thirty feet high. It consists of broken Silurian quartzite, forming a rough breccia, but distinct from the basal breccias and conglomerates of the Upper Palaeozoic, which are clearly of a detrital nature. Tracing the contact along in a north-north-westerly direction, it is found that in addition to the crush features a portion of the basal beds is cut out, the features in general therefore indicating a persistent fault along this line.

Transverse sections across the Macallister valley at intervals to the north, beyond the area included in this map, would seem to indicate similar structural conditions. The western limb of the broad anticlinal fold has been bent back to form a minor syncline, and faulted against the older rocks on the west. This same feature is recognisable still further north along this line in the map, and section of Woods' Point sheet by O. A. L. Whitelaw, and a generalised section compiled from that map and extended to the east from my own observations seems to provide a probable interpretation of the structure (Section 4). A minor fault with a north-easterly direction intersects the major one, and corresponds in position with the lower portion of Hickey's Creek, but it is the other direction which is of greatest importance.

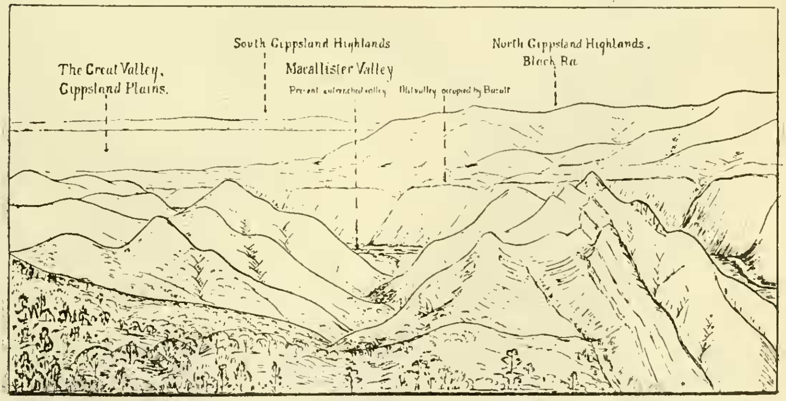
The age of this tectonic movement cannot be fixed closely. It is clearly post Lower Carboniferous, but may still be Palaeozoic, though it seems probable that renewed differential movement may have taken place along this line at successive intervals during the late Kainozoic uplift, which produced the existing highlands. The position and general direction of the Macallister valley coincides in part with this line, and some of the physiographic features suggest at any rate that its course has been controlled to some extent by this feature.

Kainozoic Basalt.—The extent of this rock is small, it is but a remnant of an extensive flow which once occupied the valley. It is about a thousand feet above the present stream bed, and was at one time clearly continuous with other more extensive fragments, which are to be found chiefly to the south in the vicinity of Blanket Hills, where the basalt forms a striking shelf about 800 feet above the existing stream, which is now entrenched to that amount along the eastern margin.

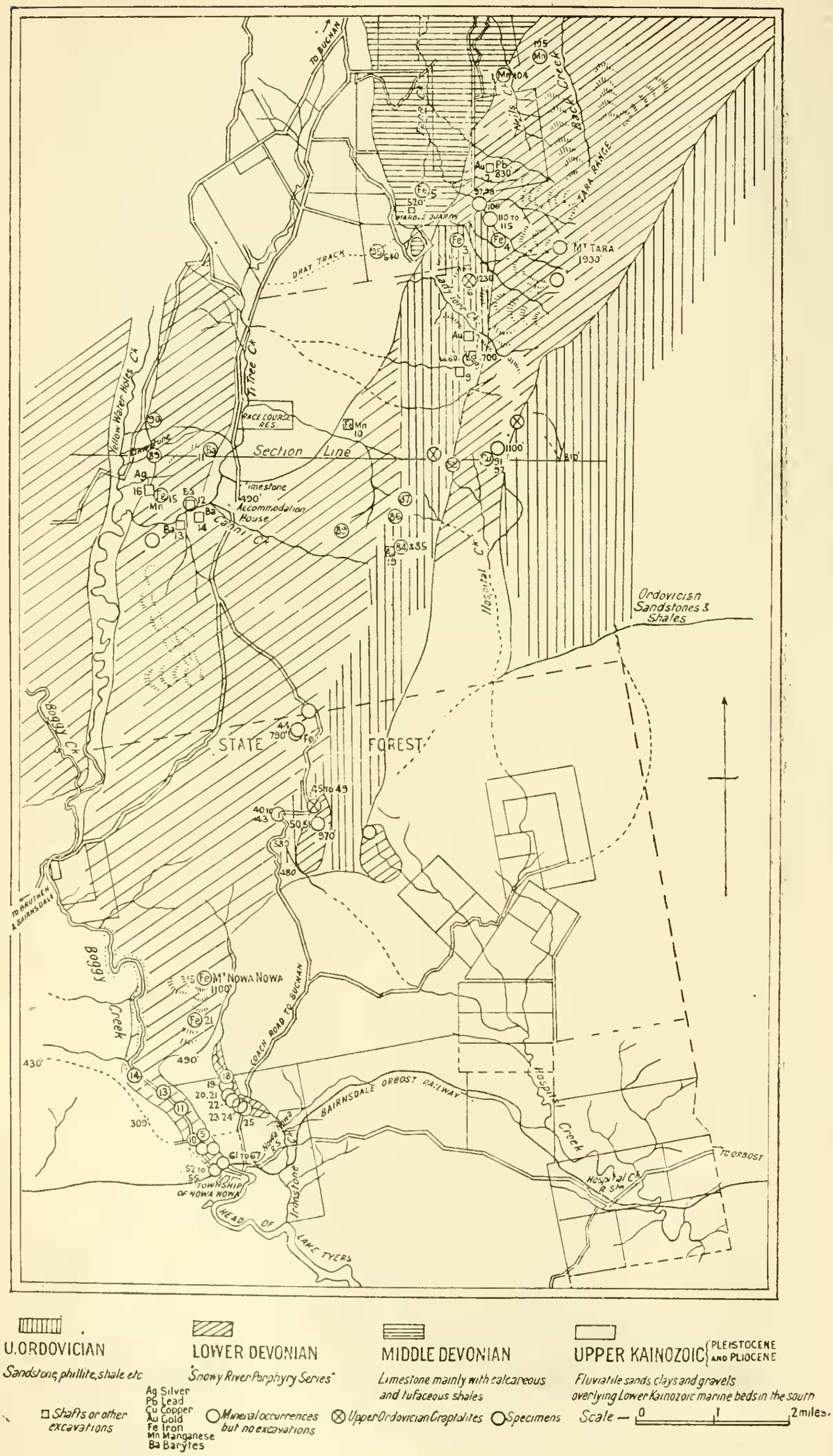
A fine view of this feature is seen from Wallaby Hill, showing also the sudden termination of the Highlands in the south, a portion of the plains of the Great Valley of Victoria, and the Southern Highlands in the distance. (See Sketch A.) The basalt of Gippsland generally is usually regarded as the Older Basalt, and may, therefore be at least pre-Miocene. There is no satisfactory petrological distinction, by which the various Kainozoic basalts can be recognised.

It is, therefore, often very difficult to correlate many of the lava flows in even adjacent areas. For instance, the high N. and S. ridge to the west of the Macallister, from Mount Useful in the south, where it forms the divide between the Thompson Valley, to Connor's Plains in the north, where it is part of the Main Divide, is capped at intervals with basalt resting on river gravels. These

Sketch A



Map 4


TO BUCHAN
Mt TARA
1930'
TARA RANGE
Back Creek
DRAY TRACK
Lady Tom Ck
Yellow Water Holes Ck
Ti Tree Ck
RACE COURSE RES.
Section Line
Limestone
490'
Accommodation House
Cahni Ck
Hospital Ck
Ordovician Sandstones & Shales
Boggy Ck
STATE
FOREST
TO BRUTHEN & BAIRNSDALE
Boggy Creek
Mt NOWA NOWA
1100'
COACH ROAD TO BUCHAN
BAIRNSDALE ORBOST RAILWAY
Hospital Creek
TO ORBOST
Hospital Ck R.Stn
TOWNSHIP OF NOWA NOWA
HEAD OF LAKE TYERS
Trinstone
U. ORDOVICIAN
Sandstone, phillite, shale etc
LOWER DEVONIAN
"Snowy River Porphyry Series"
MIDDLE DEVONIAN
Limestone mainly with calcareous and tufaceous shales
UPPER KAINOZOIC { PLEISTOCENE AND PLIOCENE
Fluviatile sands clays and gravels overlying Lower Kainozoic marine beds in the south
Shafts or other excavations
Ag Silver
Pb Lead
Cu Copper
Au Gold
Fe Iron
Mn Manganese
Ba Barytes
Mineral occurrences but no excavations
Upper Ordovician Graptolites
Specimens
Scale — 0 1 2 miles.

form some of the highest points of the surrounding highlands.

The Mount Useful Basalt is only eight miles in a straight line to the west of the outcrop here described, and yet it is 3300 feet higher. It apparently marks the line of an old valley parallel with the present Macallister, and one question that at once suggests itself is to account for this great difference in altitude. The two alternatives which seem to be most worthy of consideration are, first, that the two basalts represent flows of totally distinct periods in Kainozoic times, and, second, that if of the same age, there has been most extensive differential movement parallel with this line in late Kainozoic times; which view is correct it is impossible to say, but on physiographic grounds I am inclined to favour at any rate a certain amount of differential movement. This will be referred to again later.

In this section the rock is seen to be a typical olivine dolerite, with a well-developed ophitic structure, violet brown titaniferous augite enclosing oligoclase. Olivine and magnetite are abundant. The section from the Hickey's Creek area is similar to that from Blanket Hills, but is of a slightly finer grain, and contains more olivine. The specific gravity of the latter is 2.81.

The District of Nowa Nowa. (Map 4.).

The region here described extends from Nowa Nowa, at the head of Lake Tyers, northward to within about four miles of Buchan, a distance of about sixteen miles. It lies to the west of the Snowy River, and includes the southern termination of the great belt of volcanic rocks known as the "Snowy River Porphyries."

As previously indicated, this region was chosen for examination mainly for two reasons:—(a) To examine certain outcrops of cherty rocks, which had been briefly referred to by Dunn (24) as "Heathcotian," and (b) to study some of the features of the Lower Devonian volcanic rocks.

The late Dr. A. W. Howitt (3 and 5) described the latter series as consisting of accumulations of acid lavas and associated pyroclastic deposits, built up round a line of ancient volcanoes occurring along a meridianal fissure. Certain quartz porphyry occurrences were regarded as probably representing the stumps of some of these old volcanoes.

Since Howitt's contribution, about forty years ago, giving a general description of this interesting and important belt of rocks, there have been no important additions to our knowledge of the region.

Later field work by Murray (25), Ferguson (26), and O. A. L. Whitelaw (27), has added a little to the details concerning the distribution and boundaries in a few localities, but no further petrological work has been done, nor had any chemical analysis ever been made of rocks from the " Snowy River Porphyries."

Professor E. W. Skeats (28), in his paper on the Volcanic Rocks of Victoria, gives a summary of Howitt's description of the " Snowy River Porphyries," dealing with their distribution, geological relations and petrological character. Briefly, they form a north and south belt up to about thirty miles in width, and extending southwards for sixty miles from near the head waters of the Murray, where the highest points rise to over 6000 feet, to the head of Lake Tyers, where they pass under fluviatile and marine Kainozoic deposits at less than thirty feet above sea level. Some doubt has been expressed as to the exact age of these rocks. It has been shown clearly that they are pre-Middle Devonian, but there is some uncertainty as to the lowest limits of the series. Mahony and Griffith Taylor (29), in dealing with the geology of the Federal Territory, compare certain quartz-porphyries of that region with the " Snowy River Series," but they claim that they represent in the Federal area, an Upper Silurian volcanic activity, which continued into the Lower Devonian. In Victoria, the beginning of this important volcanic outburst cannot yet be fixed so certainly, as Upper Ordovician graptolites are the only definite fossils obtained from the older sediments, on which the volcanoes rest unconformably.

Howitt's petrological examination of this rock was of a preliminary nature, and he describes them as quartz-porphyries (in which orthoclase prevails over plagioclase, a point to be referred to again later), felstones (acid lavas), ash and agglomerates.

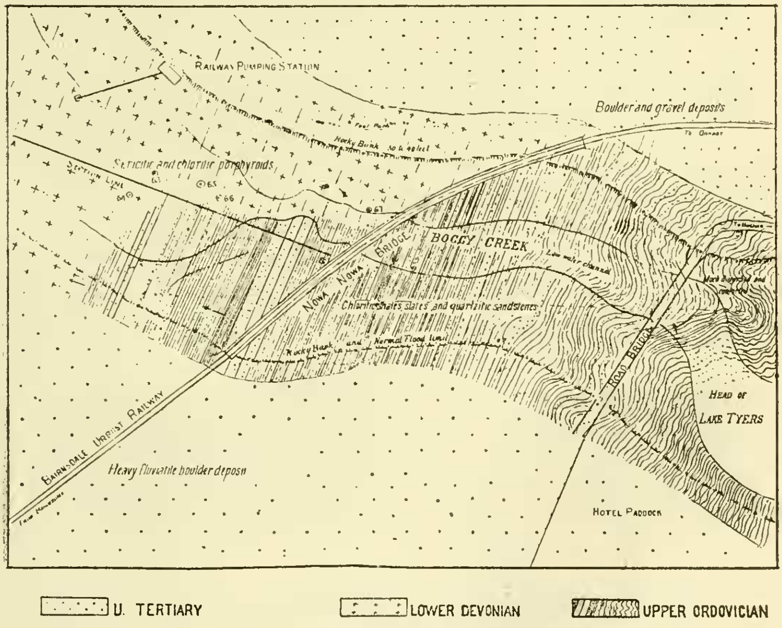
General Surface Features.—The physiography of the area under consideration will be discussed separately under the section devoted to that purpose. It will only be necessary here to mention a few salient points.

The southern portion is part of a low coastal plain of soft rocks, rising, as a rule, not more than several hundred feet above sea level. The uppermost beds consist of fluviatile grits, sands, gravels and boulder deposits, which, in the south, overlie marine Kainozoic limestones and marls, but further north than about twelve miles from the coast, they rest directly on the older rocks.

The rest of the region forms a low portion of the Victorian Highlands, most of which is below 1000 feet in altitude, and its southern border is less sharply marked off from the coastal plain than usual. Hard rocks of a varied nature have controlled largely the main irregularities of the present surface, and the principal feature is the Tara Range, which runs obliquely across the area in a N.N.E. direction. Starting towards the S.W. corner of the map, at Mount Nowa Nowa (about 1100 feet), the range continues as a rocky forest clad ridge to the N.N.E., rising in Mt. Tara to nearly 2000 feet. The rocks composing it consist of quartz porphyrite and Upper Ordovician slates and sandstones.

The most important streams are Boggy Creek and its tributary, Yellow Water Holes Creek. The former enters the head of Lake Tyers at the township of Nowa Nowa, after passing for several miles through a rocky gorge entrenched in the Porphyry Series, and exposing some of the best sections to be seen in this area. A few of the gullies on either slope of the Tara Range also provide some good exposures, but most of the area is covered with the scrub and forest, and the relationship and boundaries of the rock formations are rather difficult to follow. The task of mapping several portions was further hampered by the want of maps of any kind. The sketch

Map 5



U. TERTIARY LOWER DEVONIAN UPPER ORDOVICIAN

Scale

map therefore accompanying this paper is in many places only a very rough approximation. Most attention was given to the lower portion of the Boggy Creek, and the slopes and gullies of the Tara Range.

General Geology.

The following formations are included within the area, and will be dealt with in turn:—

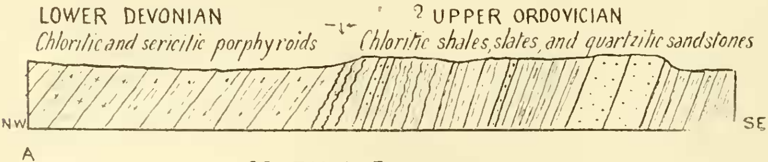
1. Upper Ordovician, consisting chiefly of highly inclined quartzitic sandstones and slates, the latter chertified in parts.
2. "Snowy River Porphyry Series"—probably Lower Devonian in age, and consisting of volcanic rocks, both effusive and pyroclastic, ranging from andesites to acid lavas.
3. Middle Devonian, comprising crystalline limestone and calcareous shales.
4. Kainozoic, ranging from Lower Kainozoic to Pleistocene.

Observations were confined mainly to the first two series.

Upper Ordovician.—This Series consists chiefly of alternating thin beds of quartzitic sandstones, mudstone, shale, phyllite and some cherty slate. There is a marked absence of the black graptolite slates, which are so characteristic a feature of the Ordovician rocks in the Wood's Point and Wellington districts.

Fossils are rare, and frequently imperfectly preserved, but all the recognisable forms have been Upper Ordovician graptolites.

The first record is due to O. A. L. Whitelaw, who obtained graptolites in a road cutting at 5 miles 50 chains from Nowa Nowa, in the Buchan Road. These were examined by the late Dr. T. S. Hall (30), and the forms identified are tabulated in the list given elsewhere. (Table 1.) Three additional occurrences found by myself are marked on the map.



SECTION E

BOGGY CREEK — NOWA NOWA

Scale,

Five separate areas have been observed within the region here discussed, where rocks regarded as Ordovician have been observed.

Three of these are quite small inliers, two occurring in the bed of Boggy Creek (Secs. C. and E.), and the third in Ironstone Creek (Sec. D.) The relationship to the "Snowy River Porphyry Series" can be studied at all these sections, but its best seen at Section E, Nowa Nowa railway bridge. (See Maps 4 and 5, and Section E.)

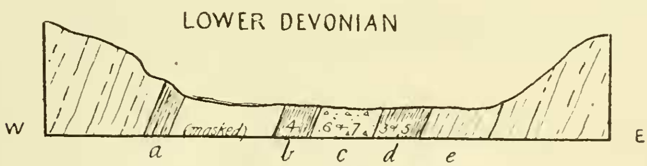
Though the strike and dip of the two series are similar in direction, the junction is seen to be unconformable.

No fossils have been obtained from any of these inliers, but the outcrops at both sections, E and D, appear to be on an extension of the strike of a larger belt to the north, where graptolites have been obtained, and the rocks are lithogically similar. All that can be said, therefore, with regard to the age of the succeeding igneous series is that it is post Upper Ordovician.

The two remaining occurrences are of larger extent, and their position will be seen by reference to Map 5. One occurs as a narrow strip about a mile in width, and nine miles long, with a general bearing a few degrees east of north. It is almost surrounded by the "Snowy River Porphyries." Its southern continuation is masked by the Upper Kainozoic sands and gravels.

These deposits also border it for about two miles along the north-western boundary.

About two-thirds of the length of the belt coincides with the crest of the Tara Range, but at the northern end it lies a little to the west of the watershed.



SECTION A. BOGGY CREEK.

a. Light green chloritic shale. b. Purple shale with sericitic markings. c. Porphyry breccia. d. Chocolate shale similar to b. e. Light coloured sheared felsite

Horizontal Scale
Vertical

6.

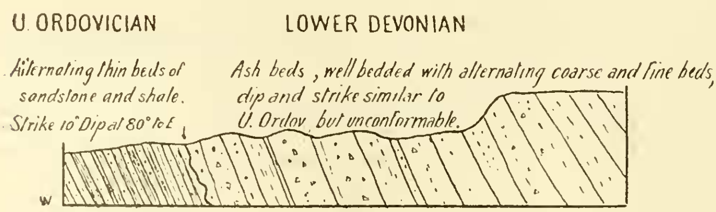
BOGGY CREEK REGION

Mount Tara Goldfield.—It is in the northern half of this Ordovician area, extending over a distance of about four miles, that the now abandoned Tara goldfield is situated (24 and 25). Numerous old prospecting shafts and open trenches occur at intervals throughout the field, but most work has been done at the northern end, in the vicinity of Lady Torr Creek, where there are a number of adits and shafts.

All the accessible adits were examined, and roughly sectioned. These observations, together with those above ground, show clearly that the rocks are very much disturbed, faulted and sheared. The line of crushing and shearing lies between N. and S. and N.N.E., and coincides roughly with that of the old mines. Though some quartz occurs, it does not appear to be in the form of a defined quartz reef, and the lode formation seems to be of the type of a fracture zone of crushed rock with some quartz and gossany material.

The strike of the rocks is generally N. to N.E., but at the northern end of the field there is much variation, north-westerly and even westerly strikes being observed close to the normal direction. This is well shown in some of the adits, where numerous faults with a generally northerly trend are revealed. Most mining appears to have been done at the "Orbost Tunnel" (Au. No. 9 on Map 4), where there are two adits and some stoping has been done along a fault line, striking 10 degrees east of north and dipping W.N.W. at about 65 degrees.

The auriferous occurrences are in general confined to the Ordovician belt, but gold has also been obtained in the porphyry, about half a mile to the north of the termination of the Ordovician. This was at the "Tara Crown," (Au. No. 2 on Map 4), where it was associated with galena. This is probably a continuation of the fracture zone, which intersects the Ordovician.



SECTION C. BOGGY CREEK

Scale

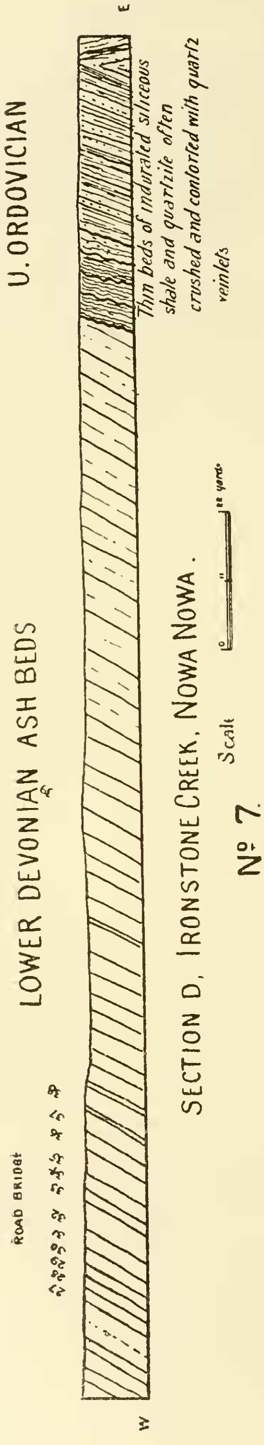
The rocks throughout the gold field, in addition to their sheared features, are frequently somewhat cherty, and on the whole are light-coloured, varying from whitish to creamish, with some superficial ironstaining along the joints and bedding planes. This light colour may be due to extensive bleaching within the zone of oxidation, for occasional loose fragments of black chert are to be found, and there is one occurrence of black chert in situ in the bed of Lady Torr Creek.

Special attention was given to the region of the old gold mines, because it was here that Mr. E. J. Dunn described the occurrence of "Heathcotian" (24), as well as Ordovician. Mr. Dunn observes that "the Tara Range is remarkable that within a mile of the Micawber lease there are three distinct series of rocks carrying auriferous vein-stones."

The three series referred to are Heathcotian, Ordovician and Lower Devonian, and the separation of the first two series appears to be based on lithological differences only, particularly the supposed significance of cherts and jasperoid rocks as a distinctive characteristic of Heathcotian; but here again, as in the Wellington district and elsewhere, this feature loses its significance, for at locality 6, north of Lady Torr's Creek, the author found Upper Ordovician graptolites in light coloured cherty rocks, and in general these rocks are so intimately associated with the more normal sediments, which also yield Upper Ordovician graptolites (locality 18), that there is no valid reason for separating them.

Turquoise.—A little turquoise was found in an old adit in the basin of Lady Torr's Creek. It occurs chiefly along the joints, irregularly distributed in a light-colored felspathic sandstone, and though of interest as another example of its wide distribution in the Ordovician, the specimens obtained did not afford much promise from a commercial point of view.

Gossany Ironstone.—Towards the northern end of the area under consideration (Fe 6 on map), there is an ironstone outcrop, consisting chiefly of limonite. It is roughly elliptical in shape, measuring about 3 chains in a north and south direction, and $1\frac{1}{2}$ to 2 chains across. Much of the limonite is hard and massive, but some contains quartz, and broken up sedimentary rock. The limits are rather indefinite, the deposit passing out into ferruginous shale much crushed and jointed. The strike of the strata is about N.N.E., and the dip appears to be easterly at a high angle. Another similar outcrop occurs about 30 chains to the S.S.W., on the fall to


E
U. ORDOVICIAN
Thin beds of indurated siliceous shale and quartzite often crushed and contorted with quartz veinlets
LOWER DEVONIAN ASH BEDS
ROAD BRIDGE
SECTION D, IRONSTONE CREEK, NOWA NOWA.
Scale
No 7.
W

Lady Torr Creek. These occurrences are distinct from the iron deposits in the porphyry, to be referred to later, the latter consisting largely of hematite, while the former appears to be the type of gossany cappings, which may develop into sulphides at a depth. No work, however, has been done with a view to testing these deposits.

Another Ordovician area still remains to be referred to. It forms part of a large region which extends to the Snowy River, and beyond into Croajingolong. Along its western boundary it is in contact with the Snowy River Porphyries. The line of junction has not been accurately traced, but it bears in a general N.N.E. direction. My own explorations here have been very limited, and were confined principally to the vicinity of the Orbost bridle track, and to a rapid reconnaisance along the now disused track to Bete Bolong, on the Snowy River. Some obscure graptolites were found close to the western boundary, with the porphyry, and are probably Upper Ordovician. The general strike as far as observed lies between N. and N.E., and it is worthy of note that this direction is characteristic of nearly all the features in this region as a whole. It is not confined merely to the strike of the strata. The belts of Ordovician, of porphyry and Middle Devonian limestone, also the longer axes of many of the granite batholiths, the major faults, and the trend of the various ore deposits, all conform approximately in this direction. It is in contrast to a north-westerly trend, which is a marked feature over a wide area to the west, and it would appear to be a continuation of the important trend lines of this direction so well developed in New South Wales.

The Snowy River Porphyry Series.—The distribution of the rocks of the series within the area here considered is shown on the map in which the characteristic N. and S. to N.N.E. trend is well shown.

Porphyritic rocks of an acid type and general pinkish to brown colour prevail on the rocky ridges, the highest point in the region culminating in Mt. Tara, about 1930 feet in height.

These rocks being of a relatively hard and resistant nature, naturally form exposures, while large intervening areas are so masked with soil that little idea can be obtained as to the nature of the underlying rock. The spoil heaps, however, of some of the now abandoned mining shafts and other excavations frequently suggest some types, showing considerable variation from the acid porphyries, and allied rocks of the ridges, and the sections in Boggy

Creek reveal the existence of bands of altered andesitic and trachytic rocks.

The fragmental character of much of the rock is frequently apparent macroscopically, and thin sections show clearly that much of the finer material too, though often much altered and silicified, is of a pyroclastic origin.

An alternation of coarse and finer-grained material, with slight indication of bedding, appears to be the general rule, definitely stratified beds being rare. Howitt (3) observes that he had only noted at one place, near Buchan, a section which suggested aqueous assortment and deposition, which he regarded as of limited extent and purely local. Though this appears to be true in the main, in the area under consideration, the outcrops in the southern extremity afford an exception, for at Section A, Boggy Creek, and Section D, Ironstone Creek, particularly, the character and regularity of the bedding are such as to strongly suggest aqueous deposition. In this region also two other exceptional features are worthy of note: the beds are highly inclined, and intensely sheared, the latter agency having converted the rocks into typical porphyroids. These are best developed at Section E, Nowa Nowa railway bridge. The schistose character is marked along the Boggy Creek Gorge for nearly a mile above the railway bridge, but gradually disappears beyond this. The direction of schistosity corresponds with that of the strike of the different beds, being in a general N. to N.N.E. direction. As the course of the stream bed is here about N.W., it is a favourable one for exposing a good line of Section. For general and petrological description, it wil be convenient to group the rocks as follow :—

(a) Porphyroids.
(b) Stratified ash beds.
(c) Trachytic and andesitic rocks.
(d) Acid porphyritic and pyroclastic rocks.
(e) Ceratophyres.
(f) Granitic rocks.

The Porphyroids.—These rocks form a rather striking group, for their schistose structure, and often also a sheen or lustre due the development of sericite give them a distinct lithological character. Their junction with the underlying sediments, presumably Upper Ordovician in age (Section E, Boggy Creek), is sharp and unconformable. They are again exposed in the bed of Ironstone Creek (18-22), and still further to the N.E. towards the head of one of the branches of Bill's Creek (below No. 68).

In general these rocks are usually light in colour, varying from light cream to pale green. Sometimes their fragmental character can be recognised macroscopically. In Section A, No. 6 specimen represents a coarse crushed porphyry breccia, with red jasper shale and chloritic inclusions. The mechanical stresses have developed a considerable amount of sericite and thin sections show in addition secondary silicification. The red jasper has the appearance of an altered igneous rock, possibly a diabase or andesite; traces of felspar can be recognised, and hematite is disseminated through it. Fragments of fine grained acid igneous rocks are also present.

On the other hand, many of the rocks of this group have a very fine texture, with their original character so altered that even thin sections may not give any satisfactory evidence concerning their primary nature, but, on the whole, the microscopic examination clearly points to the fact that they are dynamically altered acid porphyrites and ash beds.

Specimen 1, Boggy Creek, is a hard schistose rock, which in the thin section, shows a distinctly fragmental character. There is a fine micro-crystalline base of quartz and felspar, in part sericitic, and set with irregular fragments of plagioclase and quartz, the former predominating. The felspar is probably an oligoclase-albite. Vivid green chlorite is abundant as well as sericite.

No. 2 is a light grey porphyroid, the thin section showing abundant sericite and no chlorite. Small fragments of plagioclase felspar are present.

No. 18, Ironstone Creek, is a sericitic rock of similar type, with recognisable granular quartz, but all trace of the felspar has been obliterated.

No. 19, Ironstone Creek, is a coarse-grained sericitic rock, with a definite schistose structure. Occasional plagioclase fragments are recognisable, and some chlorite is present. Among the inclusions one fragment may represent an altered andesite. The result of intense stress is well shown.

A belt of these porphyroids, 10-12 feet wide, in the bed of Boggy Creek (No. 63, Map 5), is highly pyritic, and micaceous hematite is widely distributed, frequently sparsely disseminated and associated with red jasper and ordinary quartz, but occasionally moderate outcrops of fairly pure hematite can be observed. More often, however, the ore is highly siliceous and lenticular in occurrence. The iron ores, however, are not restricted to the porphyroids, but the micaceous variety appears to be the characteristic form occurring in these rocks, and the stresses to which they have been subjected may have been favourable to the production of the micaceous form of the ferric oxide.

One feature worthy of some reference, and well shown at Section E, is the fact that the porphyroids appear to have been more affected by dynamical stresses than the underlying older sediments, consisting of chloritic shales, slates and quartzitic sandstones. They therefore frequently approach typical schists in character, while the adjoining older beds still preserve the appearance of normal sediments. It is probable, however, that the two series may have been subjected simultaneously to stresses of the same order of magnitude, but the nature of the mineral composition of the porphyries and ash beds from which the porphyroids have been derived made them more susceptible to the development of new structures and mineralogical rearrangement.

Stratified Ash Beds.—These beds are best studied at Section A and C, Boggy Creek, and at Section D, Ironstone Creek. The stratification is regular, with an alternation of coarse and fine material, the dip being at a high angle, westerly in sections A and D, and easterly at C. It is well known that a sub-aerial deposition of volcanic ash may result in remarkably regular deposition, and in the absence therefore of definitely aqueous sediments interbedded with the ash beds or of the association of fossils in sedimentary material with the pyroclastic, it may not be possible to decide whether the beds in question are really sub-aqueous or not. The fine, purple shales, beds b and d, Section A, however, resemble very closely true sub-aqueous sediments, and may, in fact, be such. No. 16, Section C, may be taken as one typical example of the normal bedded ash beds, though the degree of coarseness naturally varies from bed to bed. This example is a light greenish grey granular rock. A thin section shows well the fragmental structure, with abundant chlorite, angular quartz, and some triclinic felspar and magnetite set in a micro-crystalline base of quartz and felspar, with some secondary silicification.

At Section D the beds are exposed more or less continuously for about 8 chains, and sometimes show a slight amount of schistosity. A good exposure is to be seen under the road bridge. The colour is in general grey, but darker and lighter bands with slight variations in texture bring out the thin regular character of the bedding. Numerous thin sections (27-39) show a general similarity mineralogically. No. 28 is a finely granular grey rock, with a little felspar recognisable macroscopically. In the thin section the base is seen to be slightly schistose, and micro-crystalline, consisting of felspar and quartz, and showing some secondary silicification. It is set with angular fragments of triclinic felspar, showing fine repeated twinning after the albite type, and occasionally carlsbad twinning also. Extinction measurements on several of the most suitable sections indicate that the felspar is probably oligoclase-albite. A little sericite and chlorite are also present. No. 38 is somewhat coarser in grain and of a light green colour. The fragmental character and slightly schistose structure are revealed in the thin section; angular quartz fragments are abundant, also altered felspar, and probably some scapolite. Dark, green chlorite and calcite are present as alteration products, and some fine-grained fragments probably represent altered shale.

One feature worthy of mention in connection with the microscopic examination of the above rocks is that all the identifiable felspar fragments noted are triclinic.

Trachytic and Andesitic Rocks. — In contrast to the light coloured siliceous rocks just described, another group of darker and more basic types is met with in Boggy Creek (Specimens 9-14), and so far they have not been traced or recognised beyond the restricted area, in the region here examined. They occur in definite bands, and appear to represent both effusive and pyroclastic beds. Most of the rocks of this type are very much altered, and the original ferro-magnesian minerals are almost invariably altered to chlorite.

No. 11 is a fairly typical example of the andesitic type. It is a dark rock, with pink felspar phenocrysts.

Thin sections under the microscope show phenocrysts of triclinic felspar, slightly cloudy through decomposition, of stumpy habit and with broad twin lamellae. No very satisfactory extinction measurements were obtained, but it may be oligoclase. The ferro-magnesian mineral was probably augite, but it is completely decomposed to chlorite. Magnetite is common. The base is cloudy and altered, but small felspar laths are abundant in it. The rock is regarded as an altered augite-andesite. No. 9 is more altered, showing some serpentinization, and much chlorite. The felspars are abundant and similar in habit to 11, but are kaolinized and carbonated.

No. 12 is a dark, dense rock, slightly porphyritic, with patches of red jasper. The thin section shows a distinct trachytic structure, with abundant felspar laths in a brownish devitrified base.

The largest felspar phenocrysts are inclined to be of rather stout habit, showing somewhat broad twin lamellae, and generally low extinctions, suggesting oligoclase.

The numerous felspar laths, which bulk most largely in the slide, and show simple twinning, are probably sanidine, as also are a number of definitely prismatic forms of intermediate size. Magnetite is abundant, but almost all trace of the original ferro-magnesian mineral has disappeared. Veins and patches of secondary quartz and chlorite are present, and one portion of the slide has been almost completely silicified, showing the quartz both as a mosaic and microcrystalline form stained by patches of hematite and some chlorite.

The rock appears to represent an interesting type of altered trachyte or trachytic andesite.

No. 14 is a dark grey, finely porphyritic rock macroscopically, but the thin section shows a distinct fragmental structure, with abundant angular fragments of triclinic felspar (probably an albite of the type Ab_{19} An_1). Smaller felspar laths are present, some of which are triclinic, with low extinctions, and, maybe, oligoclase, also magnetite and fragments of altered rocks similar to 12, much chloritized. The base is finely granular in part, due to secondary silicification. There are no recognisable original ferro-magnesian minerals, but chlorite is abundant. The rock probably represents an altered andesitic ash.

Acid Porphyritic and Pyroclastic Rocks.—Rocks of this type are very abundant, and show considerable variety of colour and texture. In general a prevailing red to brown colour is most common, but various shades of green to grey are also found.

Flow structure is not common, and was only noted in one place, namely, in the ridge between Ti-Tree Creek and Yellow Water Holes Creek, and W.N.W. from Beecher's.

Quartz and felspar either as fragments or phenocrysts are usually apparent macroscopically, and in thin sections the rocks of this division can generally be readily separated into two groups—

(1) Those definitely fragmental, representing altered pyroclastic material.

(2) Those of the more normal quartz-porphyrite type, probably partly hypabassal, having solidified in the fissures, or vents, through which the more superficial material reached the surface.

Both these types are well represented along the Tara Range.

(i.) *Fragmental Type.*—Sections of this type show all the larger minerals and inclusions as broken and angular fragments, with no embayment. The base is siliceous and finely granular, and among the larger fragments felspar is often more abundant than quartz, and the triclinic form distinctly predominates, orthoclase being rare.

The secondary minerals most abundant are chlorite, and occasionally calcite.

(ii.) *Acid Porphyrites (Non-Fragmental).*—The rocks of this type have perhaps a higher silica percentage than normal porphyrite, and this may in part be due to a certain amount of secondary silicification and alteration.

The fine grained base of the rock is generally affected to some extent in this way. All the recognisable felspars, however, are dominantly triclinic, orthoclase being more or less rare.

No. 100 is a medium grained porphyritic rock of a red brown colour.

In the thin section the phenocrysts have rather irregular outline, the quartz is partly rounded, and occasionally embayed. The felspars are more abundant than quartz, and occasionally have a regular prismatic outline, but more often are broken and irregular. Twinning after the albite law prevails, but occasional pericline and carlsbad types are represented. The twin lamellae vary from moderately broad to fine bands. Different kinds of felspars appear therefore to be represented. Only a few were satisfactory for determination by extinction angle. These gave readings up to 20 degrees, and are probably therefore andesine.

The optical features of several examples suggest anorthoclase, and the chemical analysis further points to some potash felspar, which, however, has not been definitely recognised microscopically. Magnetite is only moderately abundant. The base is micro- to crypto-crystalline, with some evidence of recrystallisation and silicification. Minute laths and fragments of felspars and quartz are scattered through it.

Chlorite is sparsely distributed through the rock, and calcite is present in moderate amount.

This rock is regarded as a quartz porphyrite. No. 105 is a greenish porphyritic rock, but the chemical analysis corresponds closely with that of the previous example.

The thin section is very similar. Quartz phenocrysts are a little more abundant, and some are beautifully embayed. The felspars show a similar range and variety. One example has very minute pericline twinning, and may be anorthoclase.

Iron oxides are a little more plentiful; some occur as very minute grains abundantly scattered through the rock. Corroded xenoliths of both fine grained igneous and altered sedimentary rocks are moderately numerous. There is an occasional flake of muscovite, and little chlorite but no calcite was observed.

No. 93 may be portion of an agglomerate. It contains numerous xenoliths, apparently all of igneous origin. One is an altered andesite, the others are red, fine grained felsitic rocks, stained with hematite, and showing small, partly kaolinised felspar phenocrysts. The rest of the rock is generally similar to the previous examples. Some of the quartz is rounded, but only slightly embayed.

No. 91 is a specimen from the Dominion copper mine, now abandoned. It is similar in grain, but lighter in colour than the other examples described, but on exposure suffers a superficial red discolouration, which appears to be due to the presence of some carbonate of iron. Otherwise the minerals present are similar. A little copper pyrites is present in the dump, but as the shaft is full of water, nothing could be seen as to the occurrence of the copper.

Quartz-Ceratophyre.—No. 68.—This rock is of medium grain, porphyritic, but inclined to be granular in hand specimens, and has a general grey colour. The analysis show a silica percentage of 72.41, very similar to that of the acid rocks generally of this district, but in the alkalies there is a marked difference in that soda is 6.86 and potash only 0.13.

It is very closely comparable with certain rocks, described from Navigation Creek, Noyang, by Howitt (32), under the names of quartz-mica-porphyrite and quartz-porphyrite.

Reference to the table with analysis will show the close resemblance.

Professor Skeats, in reviewing the volcanic rocks of Victoria (28, p. 187), quotes Howitt's analyses and gives some additional remarks on these rocks, describing them as quartz-ceratophyres. Referring to one example, he says, "This rock shows a microcrystalline granular ground mass of quartz and felspar, with minute microliths of chlorite, replacing probably amphibole. The porphyritic constituents are as follows:—

Oligoclase of an acid variety, showing both albite and carlsbad twinning. Quartz in corroded and fractured crystals and chlorite pseudomorphs after magnesia-iron-mica."

The above description also concisely describes the features of No. 68. The occurrence of this rock is shown in Map 4, near the head of one of the branches of Ironstone Creek. The outcrop, however, is very limited, being partly surrounded by late Kainozoic sands and gravels.

The relationship to the igneous rocks of the district is not shown, but it is almost certainly later than the earliest members of the Snowy River Series, which show here various stages of shearing with the development of porphyroids. Some of these outcrop in the stream bed a short distance below the ceratophyre.

From the chemical analysis of No. 68, applying the American Classification, it is interesting to note that it falls into the persodic Subrang, noyangose, of liparase, the per-alkalic Rang (1) of britannare, the quardofelic Order (4) of persalane. Class 1.

ANALYSIS AND MOLECULAR RATIOS AND CLASSIFICATION.

SiO_2	72.41	1.207	Quartz	29.28
Al_2O_3	14.38	0.141	Orthoclase	0.55
Fe_2O_3	2.94	0.018	Albite	58.16
FeO	0.85	0.012	Anorthite	3.33
MgO	1.18	0.029	Corundum	2.84
CaO	0.87	0.015	Hypersthene	2.90
Na_2O	6.86	0.110	Magnetite	2.32
K_2O	0.13	-	Ilmenite	0.45
H_2O+	0.67	-	Hematite	1.28
H_2O-	0.04			
CO_2	-		Class	1
TiO_2	0.26	0.003	Order	4
P_2O_5	0.17	0.001	Rang	1
MnO	0.09	0.001	Sub rang	5
Total	100.85		Magmatic Name, Noyangose.	
S.G.	2.63			

Granite Rocks.—Only one small occurrence of granite has been noted in the area included in the map. It is limited to an exposure of a few chains extent along the bed of one of the branches of the Tara Creek, No. 98. On the west it is in contact with the fragmental igneous rocks of the Snowy River Series. No evidence of contact alteration of these rocks was noted, nor have any dykes or offshoots of granitic rocks into them been observed. It is probable, therefore, that the granite is the older rock. A much more extensive outcrop of granite closely similar macroscopically, and in thin sections also, occurs a few miles to the east of the Tambo River, and the Bairnsdale-Orbost railway line intersects the southern end of the mass, showing some good sections in one of the cuttings a few miles east of Bruthen. The rock is of medium grain and pink colour, closely resembling the better known Gabo Island granite, with which it is most probably to be correlated genetically. At the locality east of Bruthen, the granite intrudes sedimentary rocks, presumably of Upper Ordovician age.

There is, therefore, no opportunity to study the relationship to the volcanic rocks of the Snowy River Series.

Another occurrence lies to the east of the Tara Range in the vicinity of the now deserted district of Bete Bolong. The granite here takes the form of two elongate elliptical masses more or less parallel, with their longer axes striking north easterly across the Snowy River. The surrounding rocks are entirely sedimentary, again presumably Upper Ordovician. This area was only very hurriedly visited, at one place on the western margin. Two types were noted, one a fine grained aplitic variety, and the other a distinctly hornblendic form without the prevailing pink colour of the types previously mentioned. Distinct contact alteration is shown in the sediments in the vicinity, characteristic hornfels being common. As the area examined at Bete Bolong was very limited, it is impossible to say whether or not the position seen is typical of the whole of the area.

Thin sections of the granite from all the above localities were examined.

No. 98, Tara Range, and that from near Bruthen, most nearly resemble each other, but hornblende is most abundant in the Bete Bolong example.

They all agree in having at least three types of felspar—orthoclase and two triclinic forms; much of the felspar is partly kaolinised, and, therefore, unsuitable for determining accurately the relative proportions, but approximately the monoclinic and triclinic forms appear to be about equal in amount. One triclinic form is well zoned with moderately broad twinning, while a less common type has exceptionally fine twinning, often of the pericline type, and with undulose extinction, indicating probably anorthoclase. The ferro-magnesian mineral is sparsely represented in No. 98, and in the Bruthen type. It is partly chloritized, but in the former it is green hornblende, and in the latter it appears to be a greenish brown biotite. No analyses have been made of these rocks, but it is probable that they would correspond fairly closely with that of Gabo Island, falling therefore into the group of Victorian alkali granites in contrast to the more calcic type of the grano-diorites. An analysis of the Gabo Island granite is included in the table for general comparison with those of the quartz-porphyrites of the Tara Range, and the similarity chemically is very noteworthy.

With regard to the Snowy River Porphyries generally, much more field work combined with chemical and petrological research is necessary before any satisfactory conclusions and generalisations can be made concerning many interesting petrological problems in this area. It is a region which offers splendid scope for future research, and it is perhaps remarkable, as Professor Skeats has already observed, that the late Dr. Howitt having done such valuable preliminary work in this series, never returned to it. Fortunately, the collection of his rocks and thin slices, together with his field notes, are in the possession of the University of Melbourne, and it has been of considerable help in connection with certain petrological points, to be able to compare my own slides with some of those of Howitt's from adjacent areas.

It is clear, however, that compared with the very careful detailed work, both chemical and petrological, given by Howitt to such areas as Noyang, Swift's Creek, Omeo, etc., this region received very scanty petrological attention, and most of the slides would seem to be among some of his very earliest work in this direction, and are often too thick or too much altered for very satisfactory determination.

One of the most interesting points, brought out as my own petrological study of these rocks proceeded, was the predominance of triclinic felspar among the phenocrysts of the acid porphyritic rocks, especially as Howitt had emphasised the reverse, namely, that monoclinic felspars prevailed. On referring, therefore, to the particular slides, which he had mentioned in this connection, it was clear that these early determinations of his required some correction and qualification for all the identifiable phenocrysts were certainly plagioclase. On account, however, of the decomposed state of the rock, some of the felspars were too kaolinized for determination. An important point, therefore, is raised, as to whether this feature concerning the felspars applies to the porphyries of this series as a whole. If so, then it may be possible to distinguish petrologically between these and certain other porphyries, macroscopically similar, but belonging to the Upper Palaeozoic of the Wellington Series.

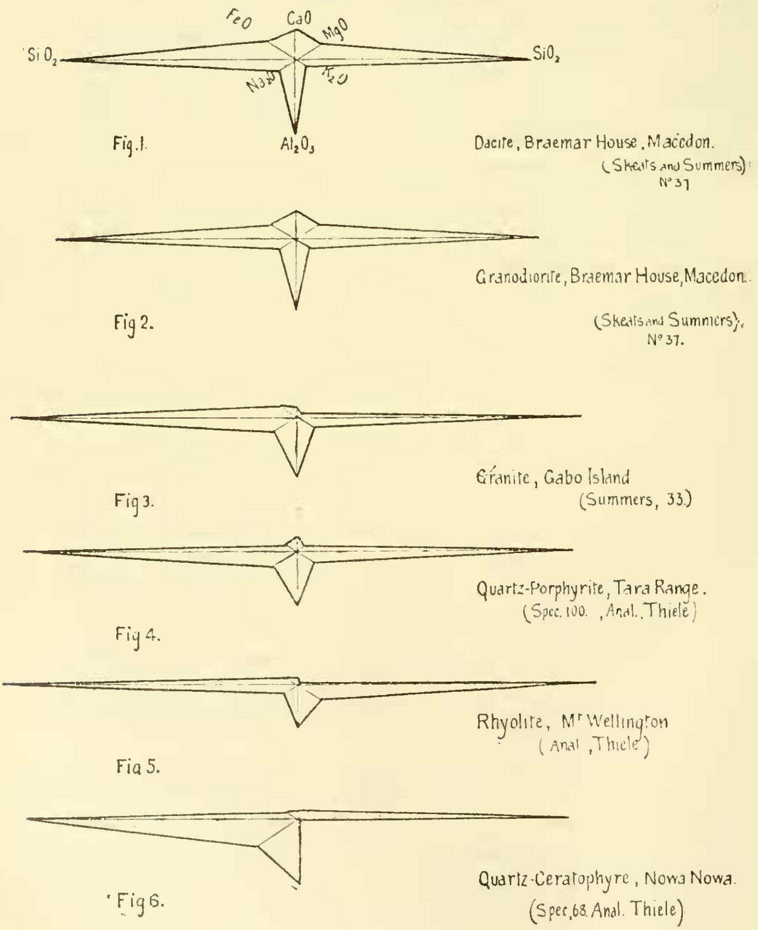
Here again, however, many more sections require to be examined in order to determine whether in their case, as it would seem to be, the orthoclase felspar predominates.

Chemical Characters and Petrographical Relationships.—Only a few analyses are available, and from a limited area. These are all of the acid rocks; none have yet been made of the andesitic types.

Making use of the instructive variation tables given by Summers (33, Fig. 3, p. 270), it is seen that the important types of Devonian

N° 8.

BROGGER DIAGRAMS



igneous rocks, plutonic and volcanic, conform closely to the graphs with the Dacites at the least acid end, and the granites of Gabo, Woolamai, etc., at the other end.

The quartz porphyrites of the Tara Range are found to occupy a position corresponding very closely with that of the Gabo Island granite, and as has been shown petrographically, it is with a granite of this type that they appear to be associated.

It would appear, therefore, that the acid rocks of the Snowy River Series belong to an acid alkali province, in contrast to the acid sub-alkali province, to which the dacites and grano-diorites belong, but all conforming to a normal variation curve.

It would be further interesting to consider the position and relationship of the andesites, but these rocks are much altered and decomposed, and, so far, no specimens suitable for analysis have been obtained.

It is worthy of note also that porphyries and rhyolites of the Wellington Series form again a more acid series than those of the Snowy River.

	1	2	3	4	5	6	7
SiO_2	72.55	73.41	71.68	70.51	72.41	72.39	72.49
Al_2O_3	11.74	12.30	13.57	14.36	14.38	14.42	13.48
Fe_2O_3	2.54	2.09	1.28	0.33	2.94	0.56	1.16
FeO	0.46	2.13	1.94	1.95	0.85	0.30	2.09
MgO	0.68	0.14	1.37	1.08	1.18	1.85	0.49
CaO	1.85	1.08	1.88	2.98	0.87	0.85	1.31
Na_2O	3.46	3.71	2.22	3.17	6.86	5.93	3.38
K_2O	4.41	4.04	3.87	3.15	0.13	1.23	4.06
H_2O+	0.41	1.51	1.24	1.18	0.67	1.13	0.76
H_2O-	0.06	0.10	0.29	—	0.04	—	0.18
CO_2	1.80	—	0.08	nil	nil	—	tr.
TiO_2	0.175	0.16	0.33	1.20	0.26	—	0.46
P_2O_5	0.14	tr.	0.03	0.12	0.17	tr.	—
NiO	—	—	—	0.08	—	—	—
MnO	—	—	0.13	—	0.09	0.01	0.13
	100.27	100.67		100.11	100.85	98.67	99.99

1. Quartz Porphyrite, No. 100, Mt. Tara Range.
—Analyst E. O. Teale.
2. Quartz Porphyrite, No. 105, Mt. Tara Range.
—Analyst E. O. Teale.
3. Quartz Porphyry, Federal Territory.
—Analyst A. G. Hall.
4. Quartz Porphyrite, Violet Town, Strathbogie Range.
—Analyst G. Ampt.
5. Quartz Ceratophyre, No. 68, Nowa Nowa.
—Analyst E. O. Teale.
6. Quartz Ceratophyre, Navigation Creek, Noyang.
—Analyst A. W. Howitt.
7. Granite, Gabo Island.
—Analyst J. Watson.

Economic Minerals.—The following minerals are known to occur in the rocks of this region :—

1. Gold.
2. Copper Pyrites.
3. Argentiferous Galena.
4. Iron minerals (Hematite and Limonite).
5. Manganese Minerals (Pyrolusite, etc.)
6. Barytes.

Most of the mining has been done in connection with gold. With most of the others only a few shallow excavations, with an occasional shaft have been opened up. Very little can be said with regard either to their geological occurrence or economic possibilities, for the reason that most of the shafts are inaccessible, and in other cases the opening up has been far too limited to enable any reliable opinion to be formed.

The position of these occurrences is shown on the map. Hematite would appear to be chiefly if not entirely restricted to the "Snowy River Porphyries." Two forms have been noted, a micaceous variety, widely distributed in the southern portions, and a massive hematite. The largest outcrop of this nature was at locality Fe 20, about six and a quarter miles north from Nowa Nowa.

Analyses of some of these ores are given in some of the Annual Reports of the Mines Department, some of them indicating ore of good quality, but insufficient work appears to have been done to determine even approximately the quantity of ore available. The same observation holds with regard to the manganese ores. These occur at the northern end of this region (Loc. M, Specimen 104), and are at the junction of the porphyry, with the overlying limestone series, and from the material exposed in the dump it would appear that they occur in the calcareous and ferruginous shales associated with that series.

Barytes is widely distributed in the porphyry, and is very common in the hills close to Beechers, Canni Creek, where there are a few shallow excavations. Most of it is iron-stained, but some good white material can be seen at Ba 11. (Specimens 13 and 74.) A small open cut here shows an irregular occurrence of Barite in thin veins and small masses replacing the decomposed porphyry.

Argentiferous galena occurs both in the limestone series and in the porphyry. Some prospecting work was in progress at the "Tara Crown," during the time of my visit, where there appeared to be a well-defined fissure lode traversing decomposed felsitic rocks in a N.N.E. direction.

Locality A, 19.—Yellow Water Holes Creek is the position of the long-abandoned "Good Hope Silver Mine." The shaft here penetrates calcareous fossiliferous middle Devonian shales.

Middle Devonian.

The Limestone Series.—Very little time was devoted to this series. An important area, however, composed of these rocks, occurs in the northern portion of this region, and is continuous with that in the vicinty of Buchan. The general features of these rocks have been well described by Howitt (3, 4 and 5), and the age is definitely fixed by the fossils as Middle Devonian.

Associated with the limestones are calcareous shales, and the whole series is in general gently folded, though some instances of high dip are to be noted. Howitt described these limestones as being laid down in troughs and basins in the Snowy River Porphyries, into which they have in many cases been further let down by trough faults. General erosion of the present cycle, and probably also that of an earlier period acting unequally on the limestones and surrounding porphyries has resulted partially in developing important basins, more or less conciding in position with some of those of Palaeozoic times in which the Middle Devonian limestones were laid down. Two basins of these types occur in this region. One is the wide, flat valley of the Ti Tree Creek, surrounded by ridges of porphyry and older rocks, save on the northern side, and the other is a narrower valley to the west, that of the Yellow Water Holes Creek.

It is interesting to note that small residual Devonian limestone occurrences outcrop in both these valleys partly buried beneath gravels sands and clay of late Kainozoic age. These are represented in Section 9. The trough faulting is assumed as probable from general considerations.

It is on the southern end of the large limestone area on a branch of the Tara Creek, in Mr. A. McRae's property, that the new Commonwealth Marble Quarry is situated.

Kainozoic.

These deposits are of considerable interest in that they throw some light on physiographical cycles preceding the present one. Their features will only be briefly referred to here. They are broadly divisable into three groups—

(a) A lower series of marine beds.

(b) An upper series of fluviatile beds.

(c) Basalt.

Both (a) and (b) are to be seen in some fine sections in the cutting of the new Bairnsdale-Orbost railway line.

The Marine beds so far noted consist of cream coloured sandy limestones and marls similar to the Bairnsdale Series, and probably Janjukian in age. These deposits can be traced from the coast to the head of Lake Tyers, where they are ferruginous, but further south along the lake cliffs the characteristic limestones are well developed. Several small outcrops are exposed in the railway line between Nowa Nowa and the Snowy River. But it is at the latter locality along the cliffs overlooking the river flats from the western side, that the finest sections are exposed. The railway cuttings here reveal cream coloured horizontally bedded limestones underlying heavy fluviatile gravels and beds of water-worn boulders.

The various sections have not been closely studied in order to determine whether or not the later marine beds of Kalimnan age are represented, but there are some coarsely bedded ferruginous grits, probably of shallow water marine origin, which may belong to this series. They appear to be unconformably overlaid by the later fluviatile beds.

So far as is known, all the marine beds in this region occur at less than 200 feet above sea level, and do not extend inland more than about twelve miles in a straight line from the coast. This limit approximately marks the position of the early Kainozoic coast line, and corresponds closely to the southern margin of the Highlands in this region.

Fluviatile Deposits.—These overlie the uppermost marine beds, and are therefore late Kainozoic, but as no fossils have been found in them, their age cannot be definitely fixed. They are generally regarded, however, on physiographical grounds as representing an important Pleistocene cycle of erosion. It is almost certain though, that some of these deposits are older, particularly those which occupy ancient drainage lines in the Highlands, beneath lava flows of basalt. In general, however, most of these fluviatile deposits may probably safely be regarded as Pleistocene.

They form an extensive superficial sheet of material, ranging from fine gravels and sandy clays to deposits of large water-worn boulders, the latter providing a very interesting miscellaneous collection of igneous and sedimentary rocks, among which various kinds of porphyries are abundant. They range in height from fifty to several hundred feet above the present river beds, and are found rising in the southern portion of the highlands to at least 800 feet above sea level.

They are to be correlated with a very general period of great fluviatile activity in Pleistocene times in Australia.

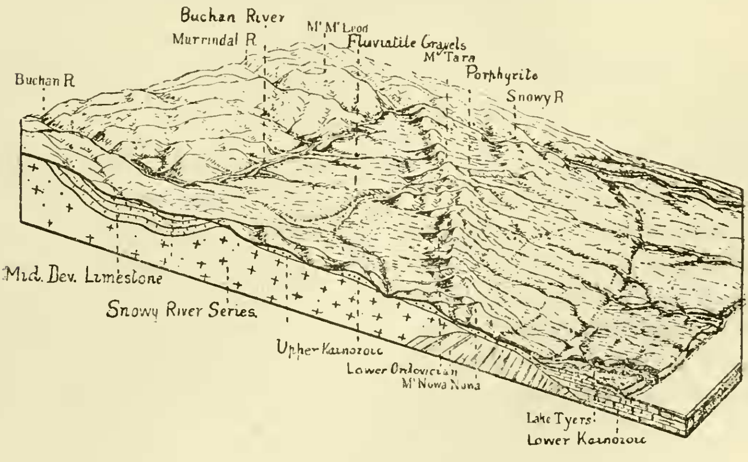
Immediately to the west of the Tara Range in the northern part of Map 4, there is an extensive basin drained partly to the south by Ti-Tree Creek, and to the north into the Buchan River, by the Tara Creek. (See Block Diagram, No. 10.) Remains of a partly-denuded sheet of Upper Kainozoic sands, grits and gravels are here preserved at altitudes rising to about 800 feet above sea level, and resting on a floor varying from Ordovician sediments to Devonian porphyry and limestone.

In general, however, they would appear to have filled in a basin corresponding in position to an ancient Devonian one, in which the Middle Devonian limestones were laid down, almost entirely burying them. Erosion of the present cycle has again partly laid bare the limestones, especially in the basin of the Tara Creek.

Basalt.—This rock has been observed only in the north-western corner of this region, in the vicinity of South Buchan, while passing along the coach road to Buchan, but its extent and character have not been observed. It is most probably to be correlated with the basalt referred to by Howitt, as occurring at Gelantipy and the Buchan River, further north, and classed by him as "Newer Volcanic."

Palaeozoic Earth History.

From the descriptive sections now concluded, dealing with two widely separated areas in Gippsland, which, however, are but very small fragments of the whole region, it will be seen that the Palaeozoic history provides a long succession of events, full of interesting structural, petrological, and other problems about which, however,



our knowledge is so fragmentary that at the best, our ideas can only be largely conjectural. It may, nevertheless, be stimulating to further research to attempt to formulate some picture of the earth history of this ancient era.

It will be seen that the same area along the Mansfield-Wellington belt, marks the site successively of marine deposition in Upper Cambrian, Upper Ordovician and Silurian times, with probable intervening periods of sub-aerial denudation. The Cambrian rocks also indicate contemporaneous volcanic action of a basic nature, the extent of which is unknown. Devonian times were ushered in with the outbreak of great igneous activity, the greatest volcanic period of Palaeozoic times in this part of Australia. Rocks of this age, however, are better developed in certain other parts of Victoria. This region was then mainly a land area, for the volcanic accumulations appear to have been almost entirely sub-aerial. Whether marine conditions supervened here as they did along the Snowy River belt is not known, for no Middle Devonian limestones have yet been recognised, but in late Devonian or early Lower Carboniferous times, a large trough, at least 100 miles long and possibly fifty miles wide was developed and occupied by a fresh water lake. The early lacustrine sedimentation which was thus initiated was accompanied in its early stage by energetic volcanic activity, both effusive and explosive, and of a highly acidic nature. Long after this rhyolitic outburst had ceased, and as deposition proceeded, there were successive outpourings of basic lavas, mostly of no great thickness, and these in turn became covered with later sediments belonging to the same period.

The succession along the Snowy River is less complete. No Cambrian, Silurian, or Lower Carboniferous sediments are known, but the volcanic accumulations of Lower Devonian times indicate very great igneous activity, which was succeeded by marine invasion in Middle Devonian into basins and troughs in the "Snowy River Porphyries."

The history recorded in these zones implies a sequence of powerful earth movements of various kinds to be discussed later. Even a casual look at the geological map of Victoria reveals a general sub-parallelism of the Palaeozoic formations, with a prevailing northly trend, and a little closer investigation indicates that certain belts have had a more varied history, therefore implying zones of greater unrest or instability, along which movements, also in some cases, igneous activities, have been periodically repeated. It has been shown that the Mansfield-Wellington belt has had a particularly varied history, and it contrasts strongly with the belt to the east, which is almost entirely Upper Ordovician, and which we may call the Dargo-Ovens zone. To the west, on the other hand, the rocks are chiefly Silurian, overlying Upper Ordovician. With regard to the eastern limits of this area, it is perhaps significant that it corresponds closely with the Cambrian outcrop in the Wellington district, and also the Howqua-Mansfield and Dookie localities farther north, in the vicinity of which rocks doubtfully referred to as the Heathcotian Series occur; while on the western side forming the boundary in part, between a Lower Ordovician region to the west, there is the important Mt. William-Colbinabbin line of Heathcotian rocks. These boundaries, or geological frontiers, may, therefore, represent certain critical lines in the past earth history, along which the struggle for mastery between conflicting earth forces has been repeatedly renewed and fought out.

Successive Distribution of Land and Water.

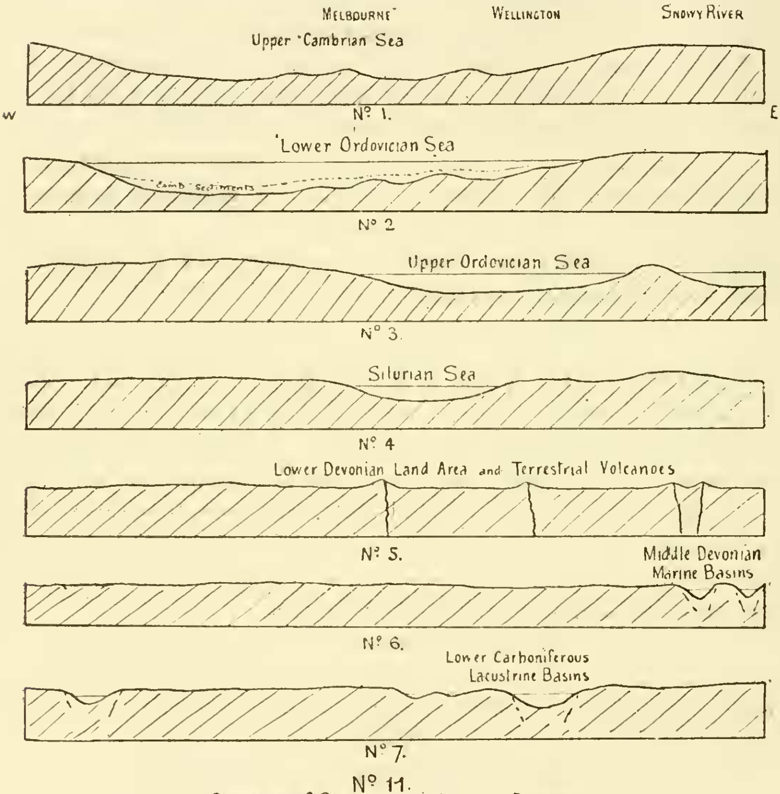
In considering the probable distribution of land and water throughout Palaeozoic times, we can only be guided by the known outcrops of the various formations, and fresh discoveries at any time are liable to modify our views, but the sub-parallel arrangement and the restriction of particular formations to certain belts or areas strongly suggest a successive alternation of land and water, which might be brought about by a long continued progressive wave-like undulation of the earth's crust.

If we consider a succession of east and west sections through Victoria during the Palaeozoic history, representing them diagrammatically to show the relative position of land and water, certain interesting features are brought out. (Diagram No. 11.)

With regard to the Cambrian times, our knowledge is far too fragmentary to enable us to form any reliable conception of the area of the sea of that period, but the pre-Cambrian rocks of Western Victoria may have formed the western limit, while on the east it may have been the belt of crystalline rocks of the Omeo zone, though there is some doubt as to whether these rocks are really Archaean or altered Ordovician.

At any rate, a probable view that seems reasonable would represent a wide Cambrian sea, occupying the greater part of the now dry land of Victoria, with ancient land masses in the east and the west (Diagram No. 11, Fig. 1).

Practically all the Cambrian rocks of Victoria so far known represent accumulations of submarine volcanic material of the nature of basic lavas and tuffs, the latter often admixed in part with fine normal sediment. The nature of the deposits, while not suggesting specially deep-water conditions, would favour the view that they accumulated over a sea floor at some distance from a shore line. The cherts and tuffs are of a uniform and fine nature, possessing none of the special features expected in those deposited under lit-



Nº 11.
Diagram of Successive Palaeozoic Basins

toral conditions. The advent of Ordovician times does not appear to have been marked by any break in deposition, but the sediments, still of a fine uniform nature, became more normal, for submarine volcanic activity had come to an end. The distribution of land and water remained much the same, and the succession on the whole, therefore, is probably a conformable one, but local gaps in the record appear to occur, notably in the Wellington area, where Upper Cambrian is in contact with Upper Ordovician. Elsewhere —as at Lancefield and Heathcote—it is impossible to determine closely where Cambrian ends and Ordovician begins.

The existing geological map of Victoria shows a striking restriction of Lower Ordovician rocks to a region lying to the west of a line approximating to the meridian of Melbourne, which would suggest an important contraction of the sea at the close of Cambrian times. Later investigations, however, indicate that this is more apparent than real.

Prof. Skeats (40) has shown that a large area in the Mornington Peninsula, originally regarded as Silurian, must now be included in the Lower Ordovician.

Several inliers of Lower Ordovician rocks are now known in the heart of the Silurian region as far east as the Mansfield district, approximately ninety miles to the east of the Melbourne meridian, and as very large tracts of the mountainous country in the eastern highlands of Victoria are very imperfectly explored geologically, it is probable that other occurrences may be revealed in the future. It is unsafe, therefore, in the light of our imperfect knowledge to generalise too positively on the distribution of land and water in early Palaeozoic times. In general, however, it would appear that there was a progressive restriction of the marine basin through Lower Palaeozoic to the close of Silurian.

In the sections therefore (Diagram 11), the relative position and extent of the successive basins are merely represented tentatively, summarising our existing knowledge of the palaeogeography of this region.

In Upper Ordovician times a marked narrowing of the Palaeozoic basin appears to have taken place, for no Upper Ordovician rocks have yet been found to the west of the Melbourne meridian. The sea may have then occupied two basins partly separated by the Omeo crystalline belt. (Diagram 11, Fig. 3.)

The next event was again a considerable restriction of marine area, drawing the Silurian Sea into a central basin corresponding to the western part of the Upper Ordovician Sea. It is not clear whether complete land conditions intervened before the Silurian Sea reoccupied the site of the western portion of that of the Upper Ordovician. The evidence of uncoformability is not conclusive everywhere. (Diagram 11, Fig. 4.) The advent of Lower Devonian times was marked by the disappearance of marine conditions altogether, and the outbreak of extensive terrestrial volcanic activity, accompanied also by widespread plutonic disturbances and earth movements. The dacites, porphyrites, granodiorites, and "Snowy River Series," and possibly also the normal granites belong to this period. The sea never again transgressed in Palaeozoic times to the extent of the early marine basins. (Diagram 11, Fig. 5.) In Middle Devonian times, the last marine deposits were formed in the restricted basins or troughs in Eastern Victoria, which were depressed below sea level, and were partly filled by limestone and calcareous shales.

The region of the depression coincided closely with that occupied by the volcanic zone of the Snowy River Series (Diagram 11, Fig. 6). The conditions of late Devonian and early Carboniferous were essentially terrestrial, but were accompanied by the development of several lacustrine basins, the greatest of which was the great Mansfield-Wellington trough, and as previously indicated, the early sedimentation was accompanied by rhyolitic effusions, and, later, by basic lava flows. (Diagram 11, Fig. 7.)

Types of Earth Movements.

The general trend of all these Palaeozoic basins appears to have been northerly, and the type of crust movement which most reasonably explains the succession of basins, parallel, but laterally shifted or restricted, is the conception of a slow wave-like undulation of the earth's crust, the basin being reciprocal feature of the adjacent land mass. It is possible to picture a prolonged progressive movement of this type to proceed with or without marked compressional or tangential movement. In the first case, the beds of each successive formation would become highly folded, and in the latter only slightly so. The idea does not preclude the possibility of periods of a much augmented rate, with important fractures and displacements.

An alternative view would be to consider the formation of a succession of basins such as here described, as being due mainly to the differential movement of great blocks or earth segments along fault planes, certain areas being alternately lifted and lowered. The whole structure of the Palaeozoic rocks, however, favours the first view, but it does not exclude the possibility and even the probability of a certain amount of faulting and block movement as well, and it would seem that as the Palaeozoic era drew to a close, after the great Devonian convulsion, though the fold movement still predominated, that of the block type became more pronounced, and finally prevailed throughout Mesozoic and Kainozoic times.

If the regional distribution of calcic and alkali igneous rock is definitely related to fold and fault movement respectively as Harker has contended, then in areas where both these types may have acted either successively or simultaneously, it would be reasonable to expect complex and apparently anomalous results with regard to the associated igneous activity. Summers (33) has reviewed the relationships of igneous rocks to earth movements in Victoria, and has opened up an extremely interesting, but very debatable subject. He has, however, shown that it is impossible to apply Harker's generalisation. It is practically certain that if the various geologists who are sufficiently familiar with the local geology were to attempt to make out a picture of the Palaeozoic history with special reference to the associated earth movements, they would differ considerably in important details. One or two events, however, stand out very clearly, and it is probable that all would agree with the view that the opening of the Devonian epoch was marked by most energetic earth folding, which intensely crumpled all the already folded pre-existing formations.

As Summers pointed out, the dominant movement was of the pacific type along north and south fold lines, but was it accompanied by great volcanic and plutonic activity, as has generally been believed? It would rather appear that the igneous phase, though related with this great crustal disturbance, lagged behind somewhat, otherwise, we might reasonably expect to find a definite linear arrangement or relationship of the igneous rocks, with some of the major fold lines. This is far from the general rule, however, in fact it is only in the case of the "Snowy River Porphyries" that a meridional arrangement is apparent. All the other occurrences appear to be distributed in a very irregular manner. Further, the volcanic deposits would appear to rest unconformably on the upturned edges of the older rocks. It appears to be the exception that the ash beds are intensely folded with the older beds.

Summers (33) has also discussed the question of the Heathcotian diabases and earth movement, and favours the idea that the basic eruptions and submarine tuffs of the Heathcotian Series are more easily explained as accompanying fault action rather than fold movement. It must be admitted, however, that the evidence is very scanty and indefinite, and is open to be interpreted in either way. The area exposed is far too limited, and the structure too imperfectly known to enable any satisfactory criticism to be made.

The Granite Batholiths and their Relation to Palaeozoic Structure.

No account of Palaeozoic history would be complete without some special reference to the abundant granite masses which penetrate the Lower Palaeozoic sediments.

Petrologically, they fall into two groups—(1) the sub-alkali group of granodiorites, (2) the group of alkaline granites. Regarding their age, they are here on petrological grounds all considered as Lower Devonian, but the alkaline granites have been sometimes referred to as probably older, mainly because they have nowhere yet been noted intruding Silurian sediments. All attempts so far to correlate the occurrence and distribution of these rocks with definite structure lines have been unsatisfactory.

The various masses are very irregular, both with regard to outline and distribution. When elongate or elliptical in shape, their longer axes just as often as not, are at right angles to the fold lines of the ancient rocks. Their contacts have not been exhaustively examined, but in many of the important instances they truncate the strata they invade, and no satisfactory linear or other distribution of the various outcrops has been recognised.

Professor Gregory, in his Geography of Victoria (34), attempted to link up certain granite masses to form the roots of what he termed the Primitive Mountain Chain, having a general east-north-east trend; and a still more fragmentary line to the south, more or less parallel, he named the Bunurong Range.

The grouping of the granite areas in this way appears to have little to support it, even from a linear arrangement, and far less from any structural consideration, as T. S. Hart has already pointed out (35).

Howitt (32) long ago recognised the importance of the factor of the assimilation of sediment and other rocks by a plutonic magma, a view which has received special emphasis and elaboration more recently by Daly.

This idea has received some support with regard to Victorian granite and allied rocks, from the observations of Howitt (32), Hart (35), Skeats and Summers (27), and Junner (38).

The petrological evidence in support of the idea is still very scanty, but structurally and otherwise it seems to provide the best conception of the great development of granite batholiths and their distribution in Victoria.

Pitch Along Anticlinal Lines.

This structural feature is one of great importance in the consideration of Palaeozoic geology in Victoria. Every area that has been closely studied has emphasised the importance of its bearing on the general structure, and it frequently also demands careful consideration in connection with the development of mining operations on the gold fields. The systematic work of the Geological Survey has added much to our knowledge concerning this feature in practically all the important goldfields, but little is known with regard to it in most other regions.

There are various questions which arise when it is made a subject for careful consideration, and two of these perhaps, stand uppermost—

(1) The age or geological epoch, when it was impressed upon the Palaeozoic formation.

(2) The dominant factor or factors contributing to its development.

Very few opinions have been expressed concerning this subject.

The late Dr. T. S. Hall (39) apparently associated its development with the movements which led to the uplifting of the existing highlands and formation of the Main Divide. This would imply a very late Kainozoic age. Its direction, however, appears to be too inconsistent and variable to be associated fundamentally with a movement which was essentially that of block movement.

T.S. Hart (35) has discussed the question and suggests a number of probable causes which are worth tabulating :—

(1) The making and dying away of individual folds.

(2) Local disturbances as a fault affecting a small area.

(3) Varying intensity of folding from place to place.

(4.) Transverse folding, simultaneous or subsequent to the main folding.

(5) Settlement of an imperfectly supported area over an invading granite.

(6) Subsequent tilting or transverse warping of folded blocks.

The above factors are all clearly competent to produce the results under discussion, and when it is considered that they may all have repeatedly contributed towards this end through past geological history, it becomes a complex problem to endeavour to apply anything approaching a definite statement with regard to its age and origin.

Hart, however, would apparently restrict the main period of development to Palaeozoic times, and this is a view most consistent with general tectonic considerations. It is unsafe to lay down any hard and fast conclusions with regard to this feature generally; each area will have to be considered carefully in detail with due regard to local and general tectonic disturbances, but one cannot help being impressed with the possible favourable conditions produced by the great batholithic disturbances of Devonian times, especially if Daly's conception of magmatic stoping and associated down-warping of overlying areas be regarded, as the most favourable explanation of the mechanism of such an important petrogenic phase in earth history.

The Relation of the Dyke Rocks and Quartz Reefs to Structure and Earth Movements.

It has long been recognised in Victoria that many of the important gold-bearing reefs can be grouped along certain more or less parallel zones, with a northerly trend, and separated by other belts of non-productive reefs or marked by the absence of reefs altogether. Most of the Victorian reefs (excepting the Bendigo and Castlemaine fields) occupy definite fissures, or are associated with igneous dykes which have intruded fracture lines. The bearing of these occurrences in general is northerly, parallel with axial lines of folding.

The age of the great reef formation is generally believed to have been Devonian, and genetically associated with the granitic intrusions of that epoch.

One belt in particular, is worthy of mention, illustrating very well the features above mentioned; namely, the Walhalla-Woods Point Zone. The prevalence of dykes, frequently of a diorite type, and auriferous reefs along this zone, is in contrast to their absence in the country to the west and east. Other such instances might be mentioned. There are also non-auriferous zones, where fractures, faults or dykes are common, about which, however, little is known with regard to their age and distribution. Many of these may not be Palaeozoic, and these are therefore not included in the present discussion.

It would appear from the consideration of the above that one phase of the great Devonian tectonic and igneous disturbance found expression in the development of lines of fracture, with a definite northerly trend along certain zones, and their infilling with igneous dykes and quartz reefs. The geological study of these areas has so far not revealed anything to suggest that these fracture lines can be regarded as planes of great differential movement on either side of which important earth blocks or segments were dislocated. They would appear rather to indicate zones of tension due to crustal adjustment, accompanying the folding and batholithic intrusion of that period.

The Fracture Line of the Snowy River Porphyries.

As indicated previously, this zone is the only one where the occurrence of certain igneous rocks other than dykes of the Devonian period corresponds closely with the general direction of the Palaeozoic trend lines. This arrangement led Howitt to postulate the idea that the volcanoes of this epoch were disposed along a meridional fissure, and though the actual position of the sites of these ancient volcanic vents still remains to be located, the view certainly offers the most probable explanation of the features as a whole.

This zone would appear also to have been successively fractured at later periods. The occurrence of the iron ores appears to be associated with one of these lines. The marked shearing resulting in the production of porphyroids is another phase, and the origin of the basins in which the limestones occur, though perhaps referable mainly to warping and erosion, may possibly be associated also with some trough faulting. Howitt has also referred to certain persistent features along the eastern side of the Snowy River Porphyries, coinciding with the valley of the Snowy River, suggesting the existence of a powerful meridional fault. Other parallel faults coinciding with the Limestone Creek and Buchan River are also suggested. (3, p. 189.)

The age, however, of these fault and fracture lines, and, in fact, their exact position also, is very indefinite. Some may be post-Palaeozoic, and it is even probable that if not originating in Kainozoic times, the plateau building period that produced the existing highlands has caused renewed movement along some of these major faults.

The undulations and gentle folding of the Middle Devonian limestones show that the fold movement, though less intense than in earlier times, still continued, and the same feature is shown by the structure of the Upper Palaeozoic rocks of the Wellington region.

Summary.

The principal features to be emphasised as a result of the consideration of the areas under discussion may be briefly enumerated as follows.—

1. *Wellington District.*

(1) The general structure of the Wellington-Dolodrook region is anticlinal, passing from a broad, simple fold in the case of the uppermost rocks to complex repeated folding in the case of the underlying old rocks.

(2) The periods of folding have been renewed from time to time, possibly on four successive occasions, but the trend of all the fold lines has persisted in a tolerably constant direction, varying between north-west and north-north-west.

(3) Denudation of the existing cycle has developed to such an extent that a complex inlier is exposed, consisting of a core of Cambrian rocks enveloped successively by Upper Ordovician, Silurian and Upper Palaeozoic sediments.

(4) The Upper Palaeozoic strata are of lacustrine origin, and those of the other periods are marine. The Cambrian limestones have yielded a definite series of trilobites, and are interbedded in basic tuffs. The Upper Ordovician rocks are black slates, chertified in part, and they contain abundant typical graptolites. The Silurian rocks have so far only yielded crinoid remains.

(5) Igneous activity is represented in two and probably three, distinct periods if we consider the district as a whole, including the Upper Palaeozoic rocks as far as Mansfield. The Cambrian series contains a pre-Upper Cambrian serpentine, with chromite and corundum derived from peridotite and pyroxenite rocks, and the Upper Cambrian contains basic tuffs. Volcanic rocks of the nature of porphyrites allied to dacites occur in the King River Valley, and others, mainly of an andesitic nature, on Fullarton's Spur, in the Macallister Valley. These are probably Lower Devonian. The basal portions of the Upper Palaeozoic (Lower Carboniferous), contain thick beds of rhyolite, and acid pyroclastic deposits. Higher up in the series there is a succession of basaltic flows (melaphyres) interbedded with the sediments.

(6) Special structural features are noted along the Macallister valley, where the Upper Palaeozoic rocks, normally dipping at a low angle, are here frequently highly inclined, and an important fault line is recognised, approximating in position to that of the Macallister Valley, and bearing, therefore, in a N.N.W. direction.

2. *The District of Nowa Nowa.*

(1) The cherts and jaspers of the region have been examined with regard to age and the origin. All the cherts observed are altered slates, and are regarded as Upper Ordovician. Definite graptolites have been found in some of them. The red jaspers are often associated with micaceous hematite, and are found chiefly in the porphyroid belt of the "Snowy River Series," and are

therefore Lower Devonian. They appear to be metasomatically altered igneous rocks, varying from andesitic to more acid types. Though widespread in their distribution, each occurrence appears to be small in extent.

(2) The oldest sediments in this region are regarded as Upper Ordovician. Definite graptolites were found in four distinct localities, and there does not appear to be any valid reason, structural or lithological, to justify the separation of any of the non-fossiliferous portions from those yielding graptolites.

(3) The igneous series known as the Snowy River Porphyries, is regarded as Lower Devonian, and rests unconformably on the Upper Ordovician sediments. The chief additions to previous knowledge concerning this extensive igneous belt are:—

(a) The recognition of porphyroids.

(b) Finely stratified ash beds.

(c) The occurrence of trachytic and andesitic rocks.

(d) The fact that the so-called quartz-porphyries are really quartz-porphyrites, triclinic felspar predominating. Two analyses of this type are given.

(e) A soda rich type is described as a quartz-ceratophyre. Both microscopically and chemically it is shown to be closely similar to certain rocks described by Howitt from Noyang, as quartz-porphyrites, and later referred to by Skeats as ceratophyres.

(f) The chemical characters and petrographical relationships of the igneous rocks are discussed, and it is shown that the porphyrites are genetically related to the alkali granites, which are characteristic of this part of Victoria.

Making use of a variation diagram to compare the various acid igneous rocks of Victoria, it is seen that the quartz-porphyrites of the Tara Range, and the alkaline granite of Gabo Island, etc., conform closely to the graphs occupying the opposite end to that of the dacites and granodiorites. It would appear, therefore, that the acid rocks of the Snowy River Series belong to an acid alkali province, in contrast to the acid sub-alkali province to which the dacites and grano-diorites belong, but conforming to a normal variation curve.

3. Under the heading of Palaeozoic Earth History, the following features are discussed :—

(1) Successive distribution of Land and Water.
(2) Types of Earth Movements.
(3) Granite Batholiths and their Relation to Palaeozoic Structure.
(4) Pitch along Anticlinal Lines.
(5) Relation of Dyke Rocks and Quartz Reefs to general structure and Earth Movements.
(6) The Fracture line of the "Snowy River Porphyries."

A succession of Palaeozoic basins of sedimentation, with a general northerly trend appears to be recognisable. These have varied in position and extent from period to period.

They have overlapped in certain instances, while in others they appear to have been laterally shifted, a land area taking the place of the basin of an earlier period, and vices versa.

The resultant formations have nevertheless a general parallel arrangement.

This succession of basins, parallel, but laterally shifted or restricted, is thought to be best explained by the conception of a slow wave-like undulation of the earth's crust, the basins being the reciprocal feature of the adjacent land mass. The basin would, therefore, be regarded as of the type of a geo-syncline. Block movement, though not excluded entirely, is regarded of minor importance during this era. The most intense folding was pre-Devonian. The great granite batholiths, though belonging to the active Devonian period of tectonic and igneous disturbances, show much irregularity of shape and distribution, and also a discordance with strike and fold lines. It is considered that their features generally are best explained by the conception of "magmatic stoping."

The consequent disturbance of surrounding and over-lying blocks of sediments may have been one of the most important agencies inducing the features of "pitch," so common throughout the Lower Palaeozoic formations. Certain zones appear to have been subjected more frequently during Palaeozoic times to tectonic and volcanic disturbance than other regions.

The Wellington-Mansfield Belt is one of these areas, the zone of the Snowy River Porphyries represents another.

The general trend of both fracture and fold lines throughout the Palaeozoic era appears to have been between north-west and northerly.

Acknowledgments.

In conclusion I wish to express my indebtedness to the following persons:—The late Dr. T. S. Hall for the careful examination of numerous Upper Ordovician graptolites; Mr. F. Chapman, A.L.S., for the identification and description of the Upper Cambrian fossils from the Dolodrook limestone; Mr. H. Herman, Director of the Geological Survey, for the loan of an able field assistant in the person of Mr. J. Caldwell, who accompanied me to the Wellington region on one of my extended excursions; Professor Skeats and Dr. H. S. Summers of the Geology School of the Melbourne University for useful criticism and advice in the laboratory; Mr. W. Thorn, Chief Mining Surveyor, for access to certain mining surveys of assistance for field work; Mr. J. Dunn, of the Lands Department, for frequent advice concerning maps and plans concerning some of the regions included in the field work. Last but not least I wish to include my father, whose untiring and sympathetic help in the field has been extended over many years on numerous excursions in this region.

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